| Unit 6: Introduction to Quadratic Functions | |
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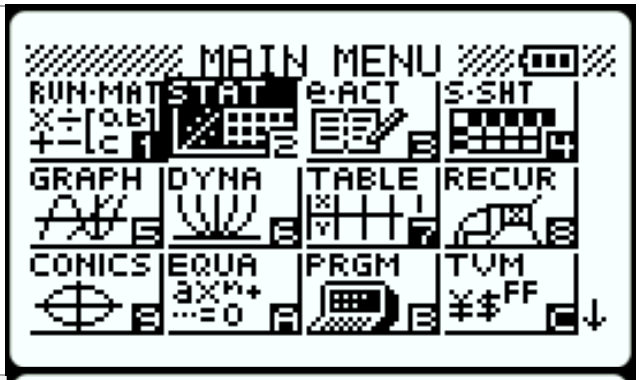
| Scientific Calculator Required | Lessons 14 |
| Graphing Technology Required | Lessons 4, 6, 11, 12, 14, 15, 17<br>(Optional – Lesson 13)<br><br>Practice Problems<br>Lessons 1, 6, 7, 9, 13, 14, 16, 17 |
| Graphing/Spreadsheet Technology Recommended | Lessons 1, 2, 4, 6, 7 |

## Lesson 1 – Investigating Quadratic Functions Using Stats Plots

**(Example: IM Lesson 1.3: Plotting the Measurements of the Garden)**

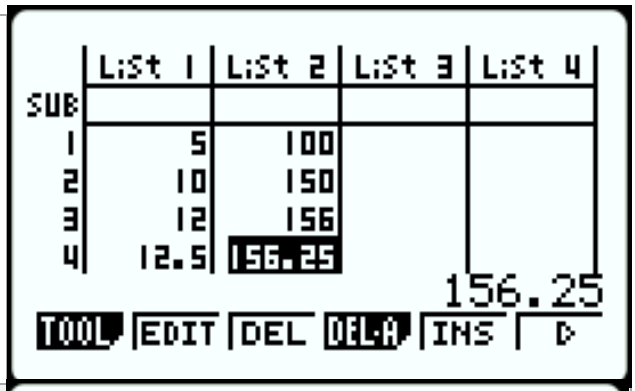
1. In this activity, students are asked to plot possible lengths and areas of the garden from Exercise 1.2. In that activity, students were to create a table of possible lengths and corresponding areas of a rectangular garden enclosed by 50 feet of fencing. We will be making a scatter plot of the data to observe "a different kind of change" in this problem.

   Press MENU, 2 - STAT to enter our data into lists.

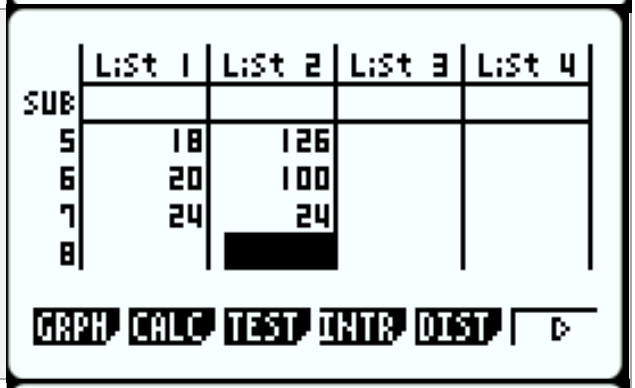



2. If there is data already present in your List 1, there is a quick way to delete all the data. Press F6 - ▷, then F4 - DEL·A for **DELETE-ALL**. A pop-up window will open to confirm your choice. Press F1 to choose **Yes**. Highlight data in other Lists and repeat for each column of data to be erased.

3. Now that our data has been cleared, enter in values for the length of the garden in **List 1**, and the corresponding area in **List 2**. For this example, I am entering the 7 points given in the Student Sample Response online. The first 4 points are to the right. Students' tables and answers will vary.

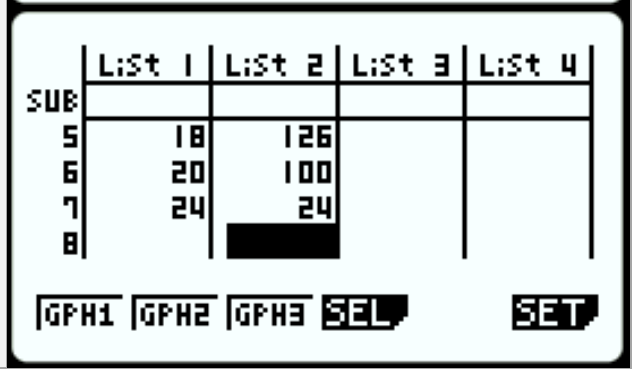



4. The last 3 points are shown to the right. Now that our data entry is complete, we want to Graph the XY Scatter plot. Press F6 - ▷ twice to return to the original menu in which F1 - GRAPH is shown.




5. Press F1 - GRAPH, followed by F6 - SET to enter **Graph Setup**. Here we want to arrow down and select Scatter for the Graph Type. X List and Y List will default to List 1 and List 2; which are correct for our data.


6. Press EXIT to return to the data lists.



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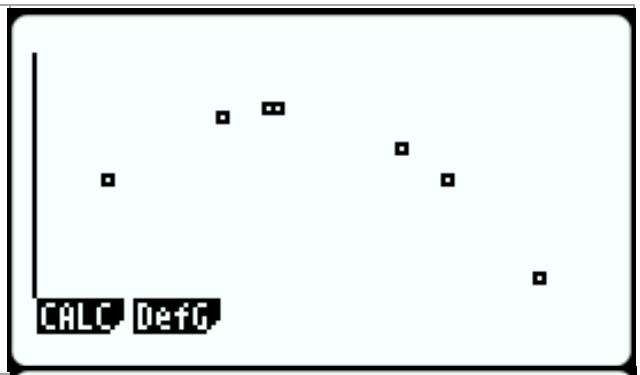
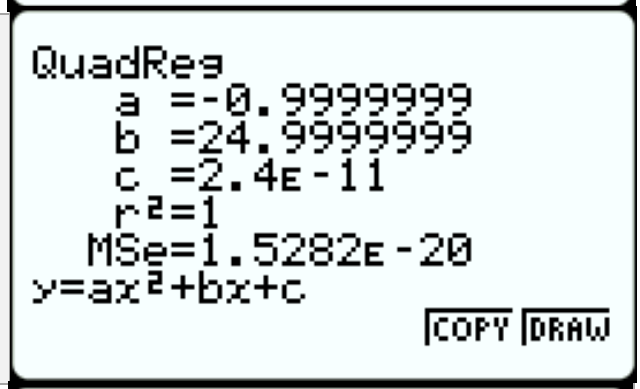
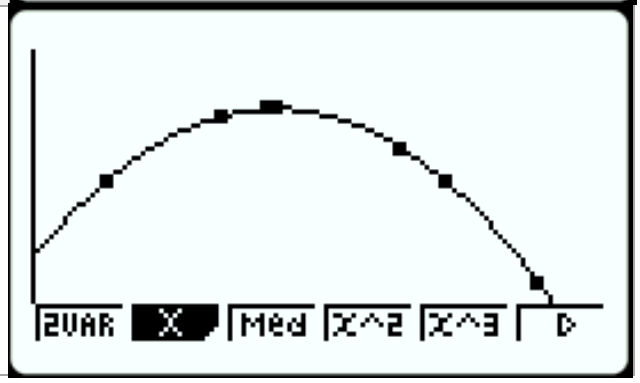
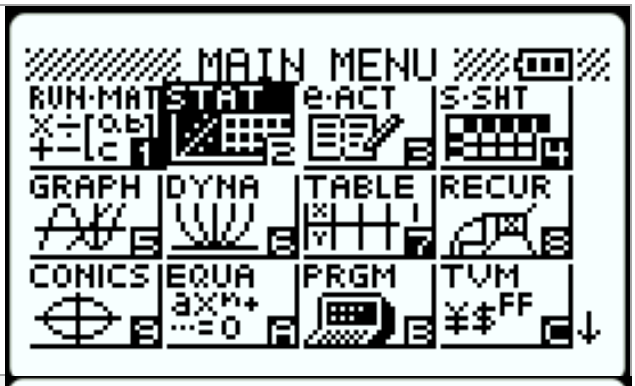
| 7. Press F1 - GPH1 to view the scatter plot. |  |
| 8. **Extension:** Recall from Unit 3: Two-Variable Statistics that we can use scatter plots to find models that fit data. The focus in Unit 3 was linear regression models. From the scatter plot, press F1 - CALC, and then F4 - x^2 The quadratic regression equation for this model is now displayed.<br><br>**Note:** Adding more points to our list will make the results more exact. |  |
| 9. Pressing F6 - DRAW will plot this equation onto the data plot; showing a perfect fit to our entered data points. |  |

## Lesson 2 – Comparing/Contrasting Linear and Quadratic Functions Using Stats Plots

**(Example: IM Lesson 2.2: Patterns of Dots)**

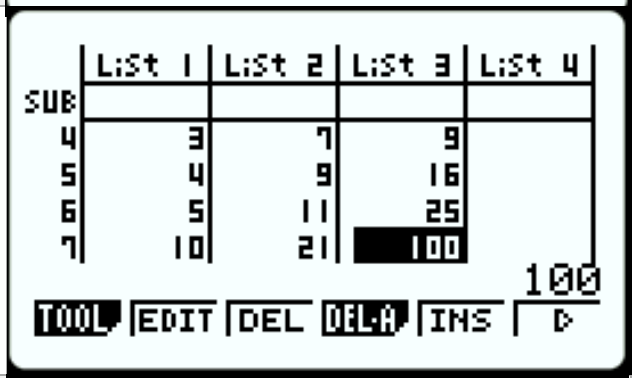
1. In this activity, students are asked to plot the number of dots from two patterns of dots.

   Press MENU, 2 - STAT to enter our data into lists.

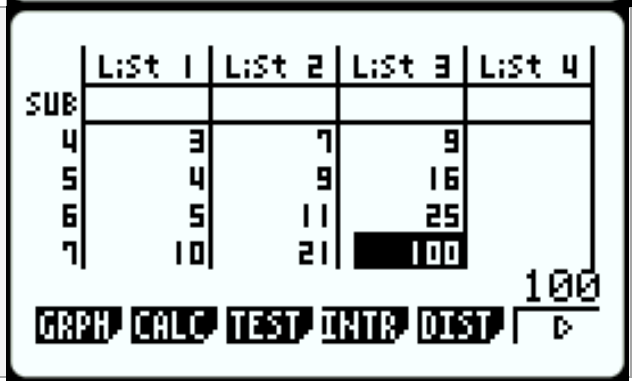



2. To quickly delete prior data, press F6 - ▷, then F4 - DEL·A for **DELETE-ALL**. A pop-up window will open to confirm your choice. Press F1 to choose **Yes**. Repeat this step to clear each list. We will use **List 1** through **List 3** to do this exercise.


3. Complete the table and enter the step value in **List 1** with the corresponding number of dots for each pattern in **List 2** and **List 3** accordingly.




4. Press F6 - ▷ twice to return to the original menu with F1 - GRAPH is shown.



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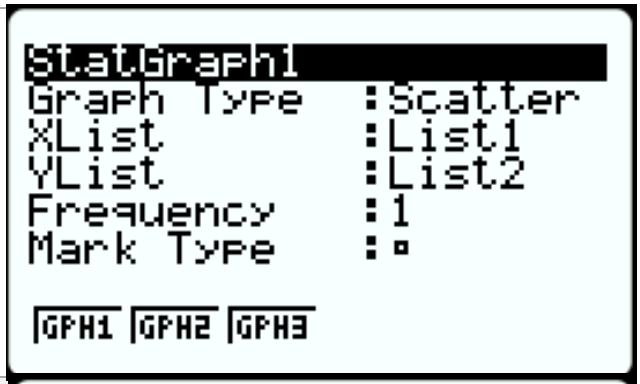
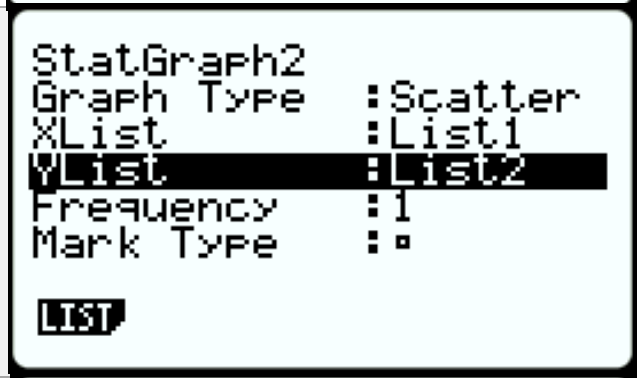
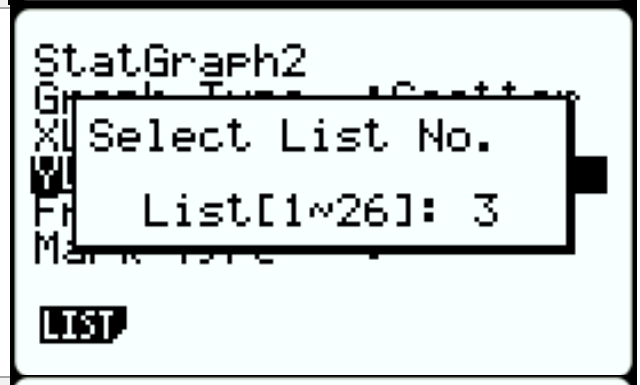
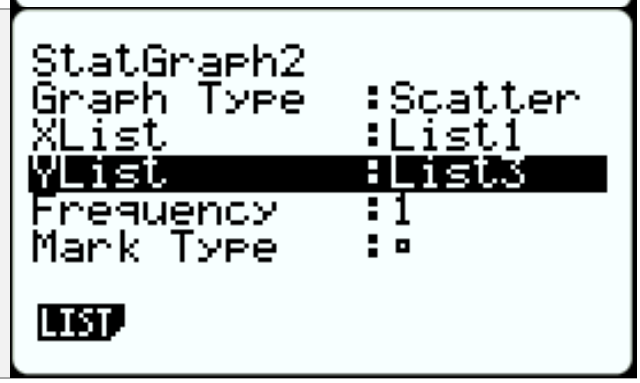
| 5. Press F1 - GRPH, followed by F6 - SET to enter **Graph Setup**. Here we want to arrow down and select **Scatter** ( F1 - Scat ) for the **Graph Type**. **XList** and **YList** will default to **List1** and **List2**; which are correct for our Pattern 1 data. Return to the top, highlighting **StatGraph1**. |  |
| 6. Next, we will set up Graph 2 to plot our 2nd set of pattern data. Press F2 - GPH2 to view the current settings for Graph 2. Follow the steps above to set the graph type to Scatter. Arrow down to **YList**. We will need to change the **YList** from the default of **List2** to **List3**. |  |
| 7. Press F1 - LIST to change the data list for the **YList** of the plot. For the second pattern data we want **List3**. Enter **3** in the pop-up window. |  |
| 8. Press EXE to save the setting. |  |

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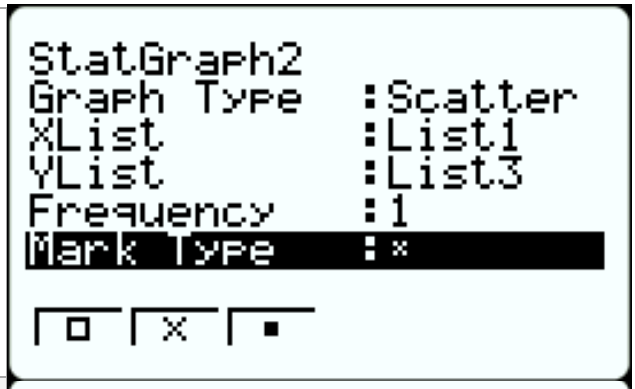
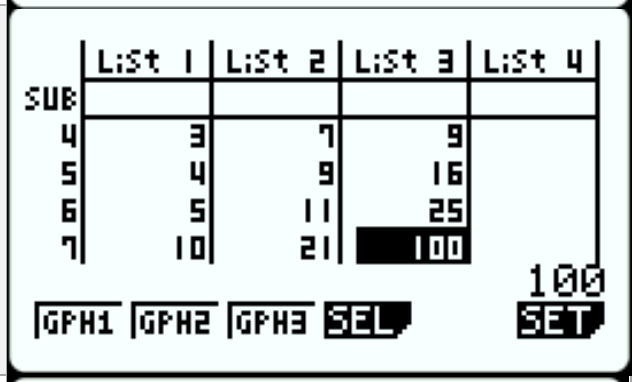
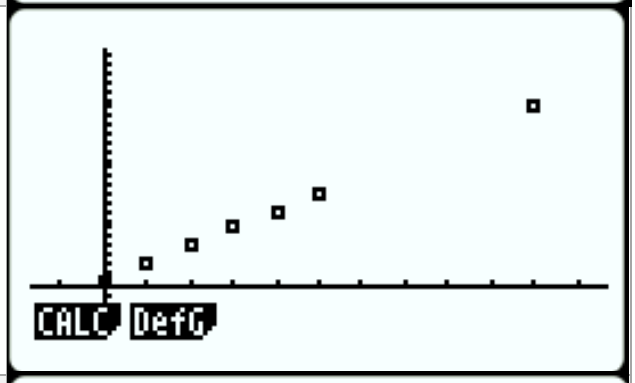
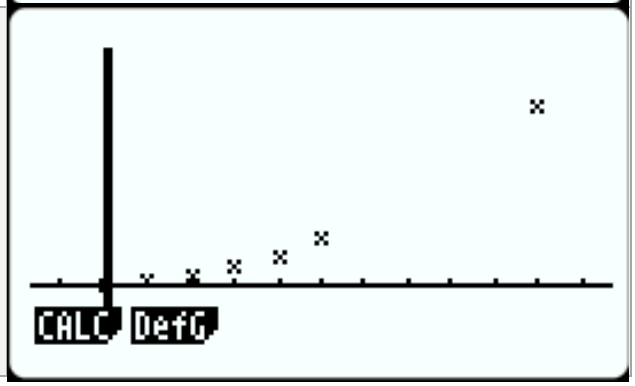
| 9. The **Mark Type** can also be changed on this page too; especially if you plan to graph both on the same axes. Arrow down to choose the **Mark Type** using F1, F2, or F3. |  |
| 10. Press EXE again or EXIT to return to the data lists. |  |
| 11. To see the first pattern of dot's plot, press F1 - GPH1. |  |
| 12. Press EXIT to return to the data list to choose the other graph. Press F2 - GPH2 to see the second pattern's plot. |  |

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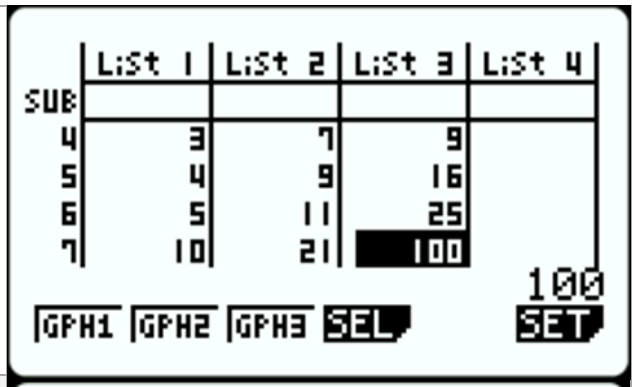
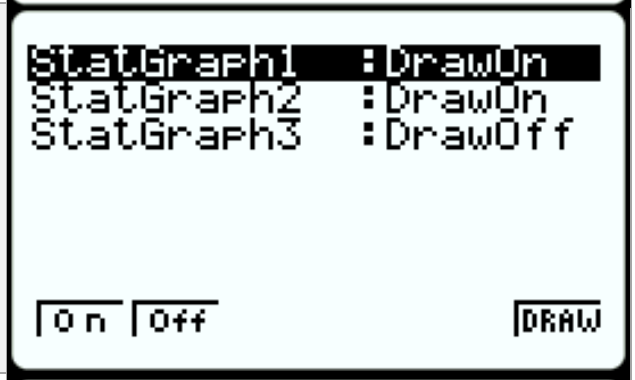
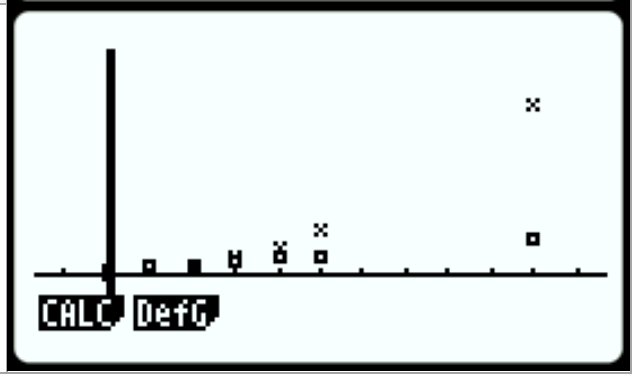
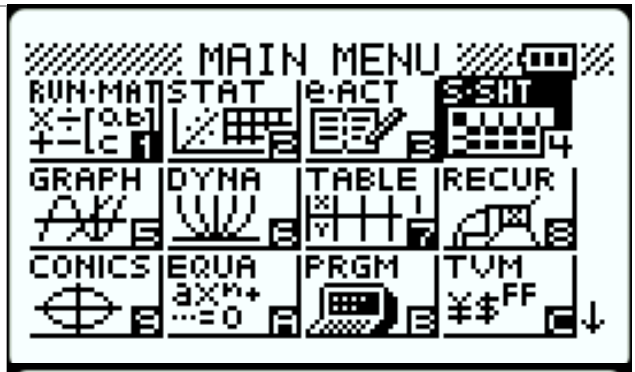
| 13. Press EXIT to return to the data list. There is also the option to overlay both graphs on the same grid. Press F4 - SEL for **Select**. |  |
| 14. Use F1 to toggle both **StatGraph1** and **StatGraph2** to **DrawOn** . |  |
| 15. Now press F6 - DRAW to see the graphs superimposed on the same axes. |  |

## Lesson 4 – Comparing Exponential and Quadratic Functions Using Spreadsheet Plots

**(Example: IM Lesson 4.2: Which One Grows Faster?)**

1. So far in this unit, we have used the **Stat App** to plot points and graphs of data points. This lesson requires us to create a table to plot and then calculate the growth factor between each consecutive point. To best achieve both criteria, we will use the **Spreadsheet App**.

   Press [MENU], [4] - [S-SHT] to enter our data into a spreadsheet.

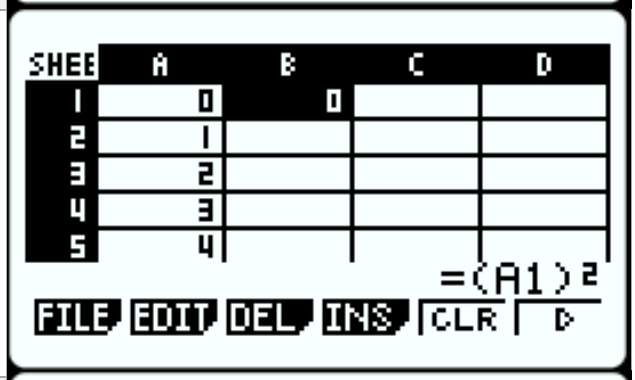



2. Spreadsheets work like data lists. In **Column A** enter the step number of the pattern.

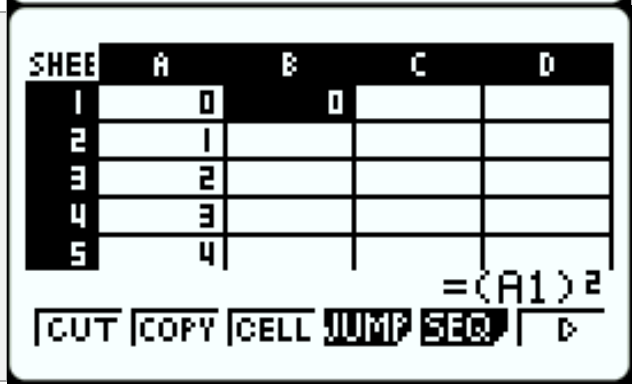

3. Enter the corresponding number of squares for **Pattern A** in **Column B** and for **Pattern B** in **Column D**. There are 3 ways to input data:

   **i.)** Data can be entered manually per cell.
   **ii.)** A formula may be used for the 1st cell, and then use copy-paste to each remaining cell in the column.
   **iii.)** The Fill command may b**e** used.

   Way **ii.)** will be demonstrated for **Column B**. Enter in **Cell B1** the formula **=(A1)²**.




4. When entering formulas, the **= sign** must be used before the formula entry. Without the **= sign**, the calculation will be performed but saved as a numerical output only. Since we used the **= sign** in Cell B1, we can copy the cell and paste it in each cell below in our table. Press [F2] - [EDIT] to see the Edit menu.



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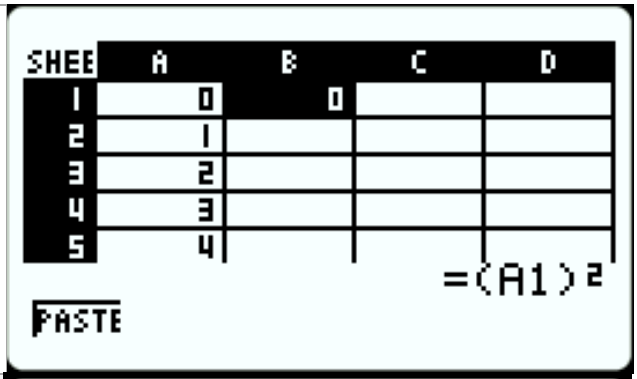
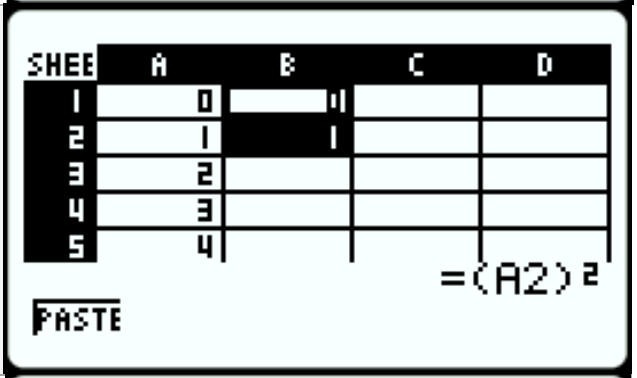
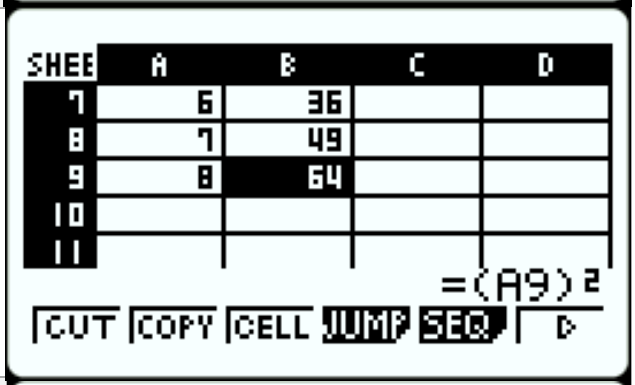
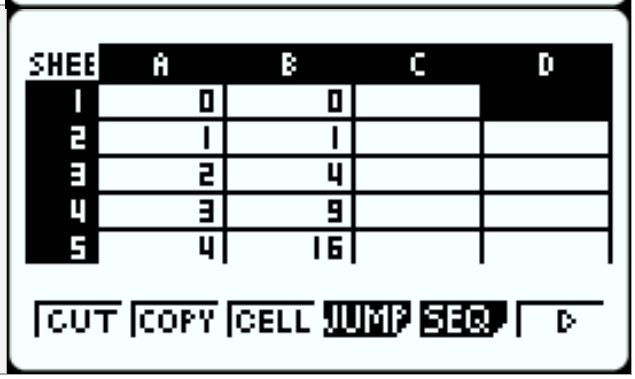
| 5. Again, Press F2 - COPY to copy the formula of **Cell B1**. |  |
| 6. Arrow down to **Cell B2**, and press F1 - PASTE |  |
| 7. Repeat the process in **Step 6** to complete the values in **Column B.** When complete, press EXIT to return to the **Edit menu** shown**.** |  |
| 8. For **Column D** of our spreadsheet**,** we will enter the number of squares in **Pattern B** by method **iii.)** using the **Fill Command**. Use the arrow keys to move to **Cell D1**. |  |

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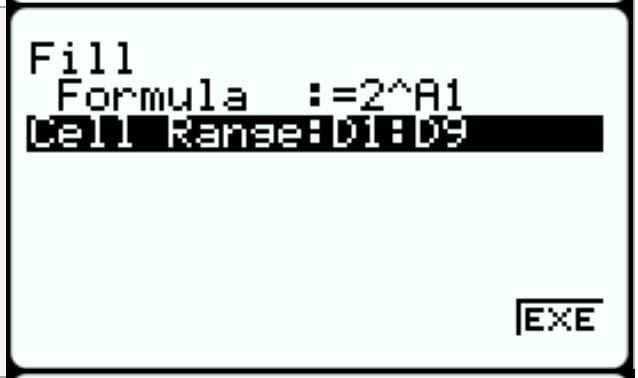
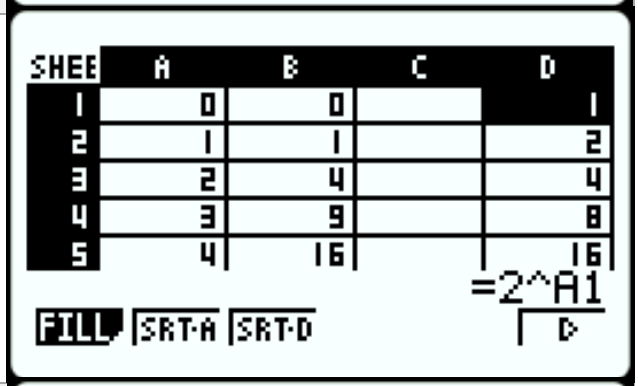
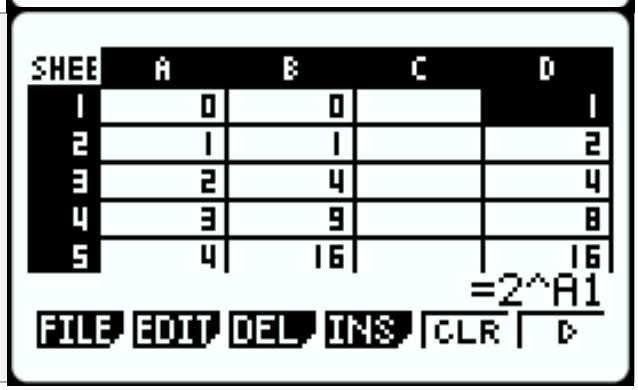
| 9. Press F6 - ▷ to see more of the **Edit** menu. Next press F1 - FILL to access the **Fill Command**. |  |
| 10. Arrow right and enter the formula for **Pattern B**; **$=2^{(A1)}$** Press EXE, then edit the Cell Range from **D1:D1** to **D1:D9** by using the right arrow to move over to the second 1 and changing it to a 9 using the **DEL** key. Press EXE again to enter the corrected range. |  |
| 11. Pressing either EXE or F6 - EXE will return to the spreadsheet view where **Column D** is now filled. |  |
| 12. Next, we can plot the values from the spreadsheet as well. Press EXIT until you are back to the main spreadsheet menu shown. |  |

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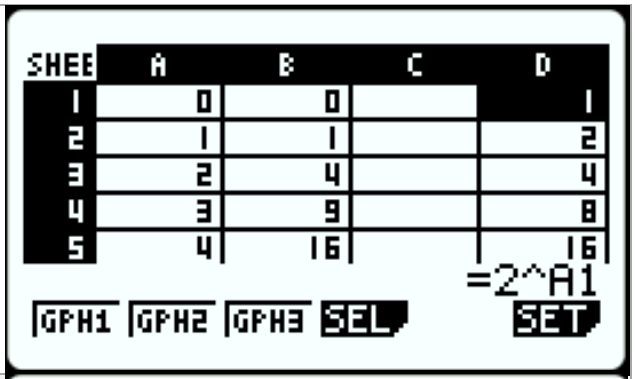
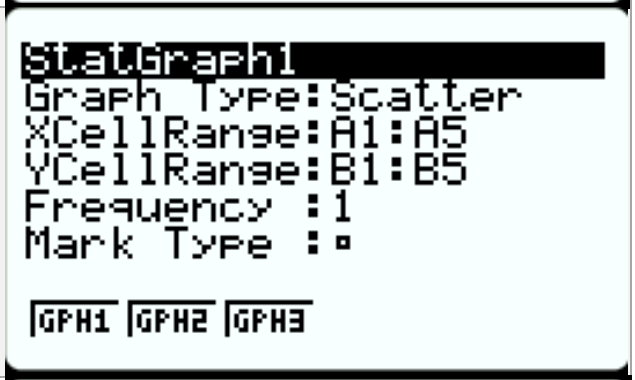
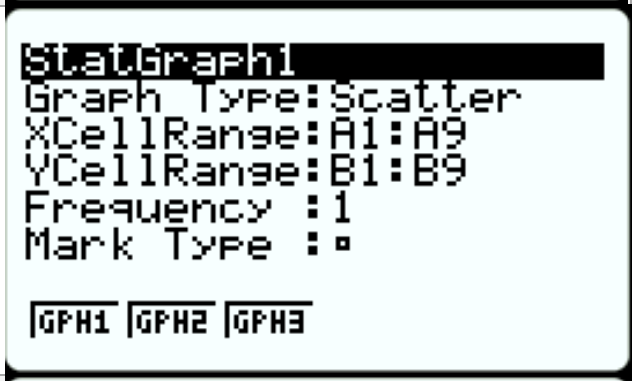
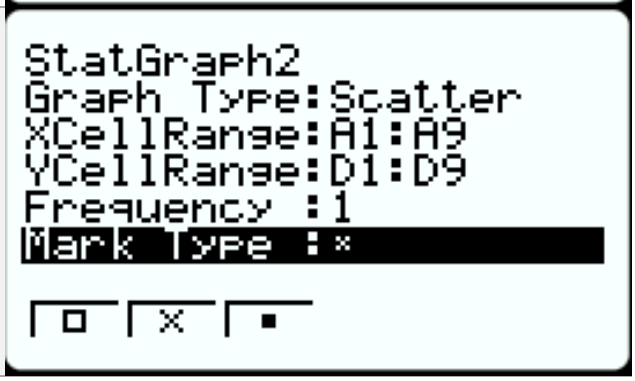
| 13. Press F6 - ▷ once, then F1 - GRPH to view the graph menu. |  |
| 14. Now, press F6 - SET to adjust the graph settings. |  |
| 15. Arrow down and adjust the settings to match the correct graph type (Scatter) and the correct cell columns and data lengths as shown to the right. |  |
| 16. Next, press F2 - GPH2 to adjust the settings for our graph of **Pattern B** data. Adjust the graph type and cell ranges to match the spreadsheet as shown to the right. |  |

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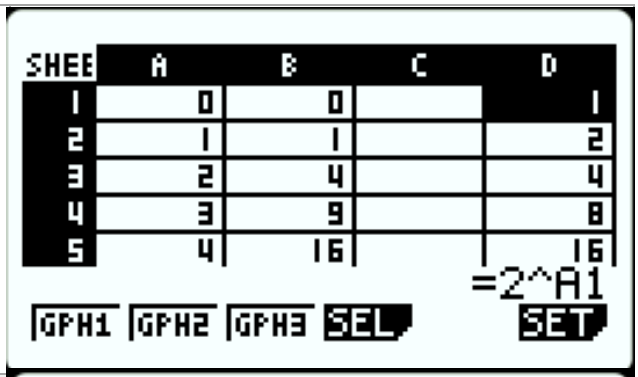
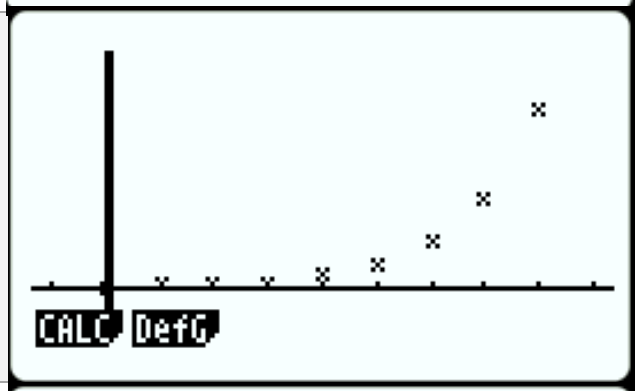
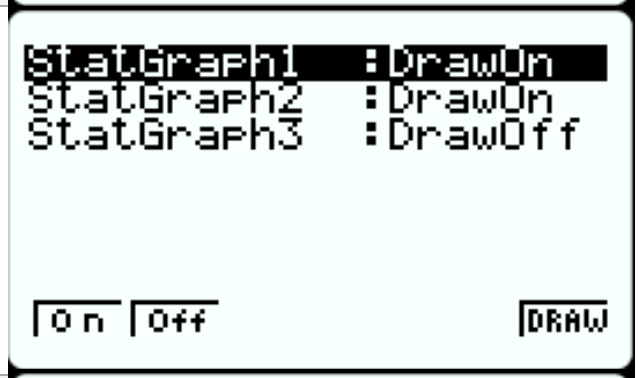
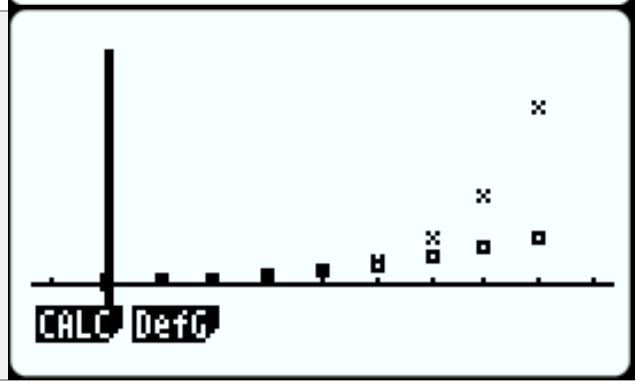
| 17. Press [EXE] to return to the spreadsheet as shown. |   |
| 18. Press [F1]-[GPH1] or [F2]-[GPH2] to see each graph individually. (**Pattern B** graph shown to the right.) |   |
| 19. Press [EXIT] to return to the spreadsheet with the graph menu shown in Step 17. In order to view both graphs on the same axes, press [F4]-[SEL] and turn both **StatGraph1** and **StatGraph2** to **DrawOn** using [F1]-[On]. |   |
| 20. To view both graphs on the same set of axes, press [F6]-[DRAW]. |   |

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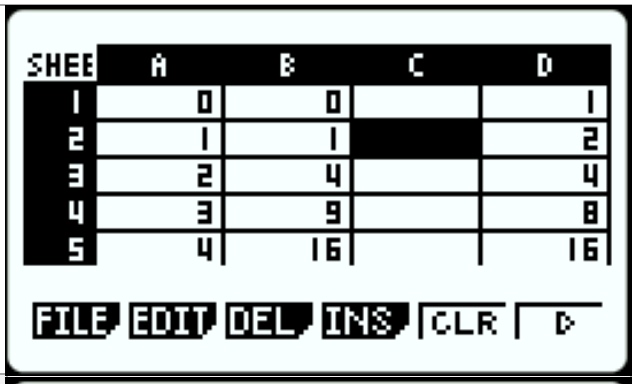
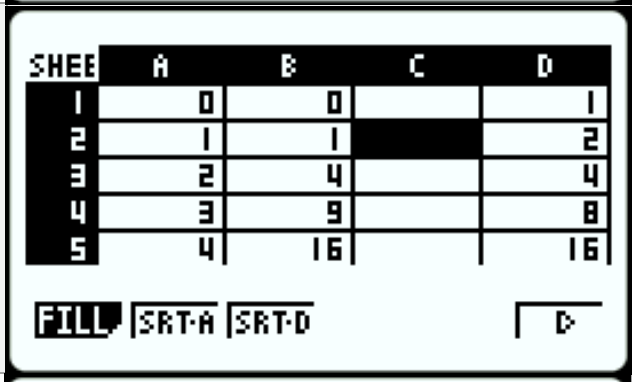
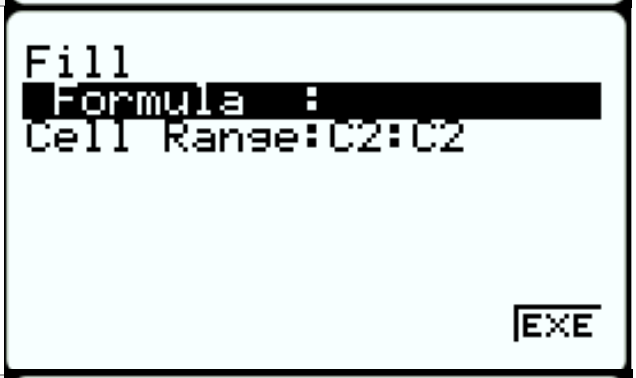
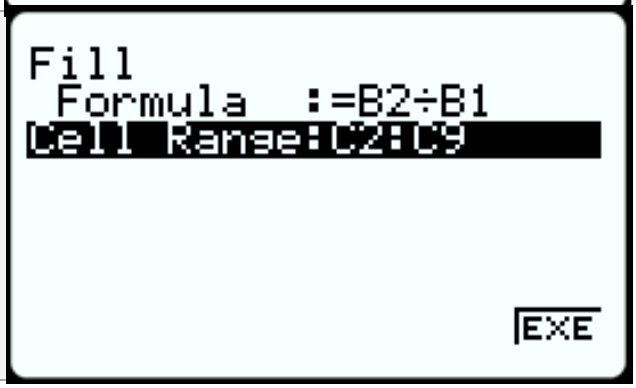
| 21. To examine the growth factor from point to point in each graph, return to the spreadsheet by pressing [EXIT]. Press [EXIT] again to return to the main spreadsheet menu. Use the arrow keys to move to/highlight **Cell C2**. |  |
| 22. Let's use the **Fill Command** again to complete the values for the growth factor for Pattern A. First press [F2]-[EDIT] followed by, [F6]-[▷] to access the **Fill Command**. |  |
| 23. At this point, press [F1]-[FILL] to view the **Fill Command Template**. |  |
| 24. As with any formula, begin with entering an **= sign.** To calculate the first growth factor in **Cell C2**, enter **=B2/B1** for our formula. Use the [ALPHA] **Key** to access the cell letters for your formula. Press [EXE] when finished to then edit the **Cell Range**. Use the arrow key and **DEL** keys to change the second 2 to a 9 as shown. Press [EXE] when finished. |  |

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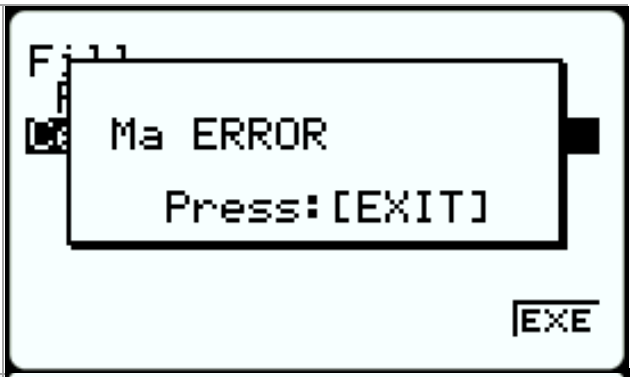
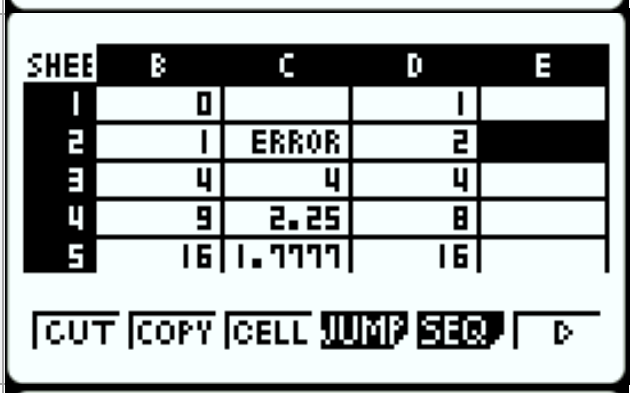
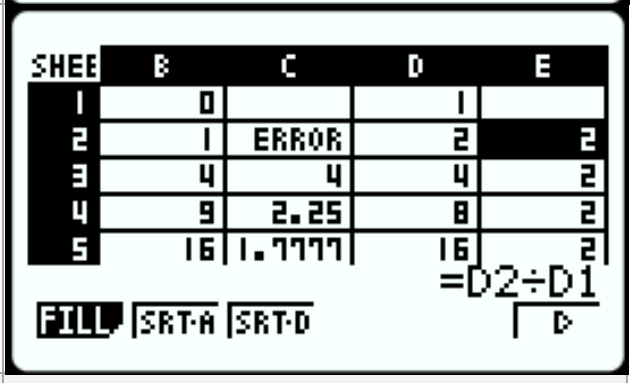
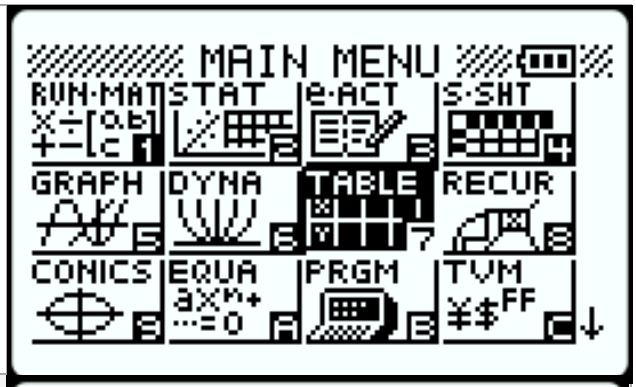
| 25. Press [EXE] again to fill in your spreadsheet. Notice that this gives an error, as for this first value in Cell C2 we are dividing by zero. Press [EXIT] twice and the values will be there within the spreadsheet. |  |
| 26. Next, we will calculate the growth factors for **Pattern B**. In this lesson, multiple ways to insert and fill formulas have been shown. Use the arrows to move to **Cell E2**. |  |
| 27. Choose one of the ways to complete the growth factor column (**E2:E9**). I will use the **Fill command** again. The Error message will again show, as the calculator refreshes cells in the entire spreadsheet. Press [EXIT] twice to return to view the spreadsheet. |  |
| 28. As students compare the values of the growth factor for each pattern, they should notice that in the long term, doubling; or the exponential function; will outperform the quadratic model. | |

## Lesson 5 – Modeling the Height of an Object in Freefall

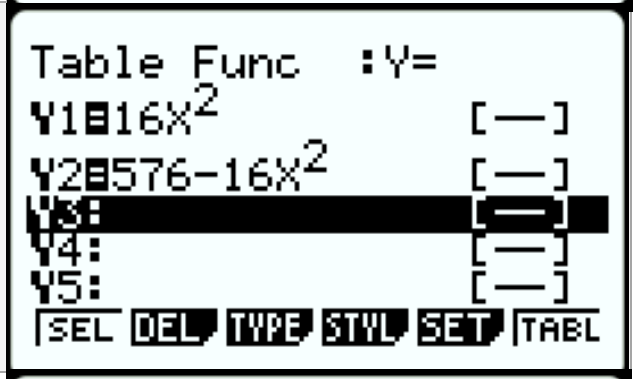
**(Example: IM Lesson 5.3: Galileo and Gravity)**

1. In this activity, students are asked to compare two students tables, and then compare their graphs.

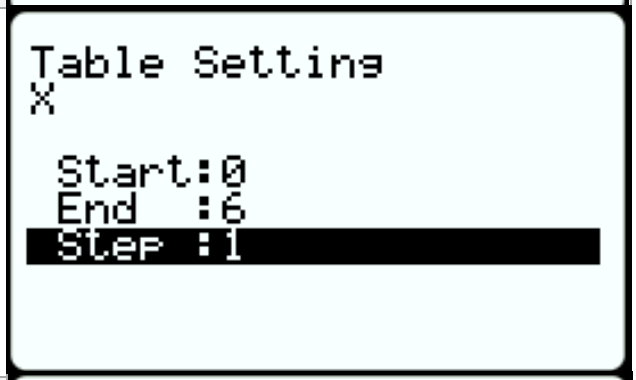
   Press MENU, 7 - TABLE to view their data in a table.



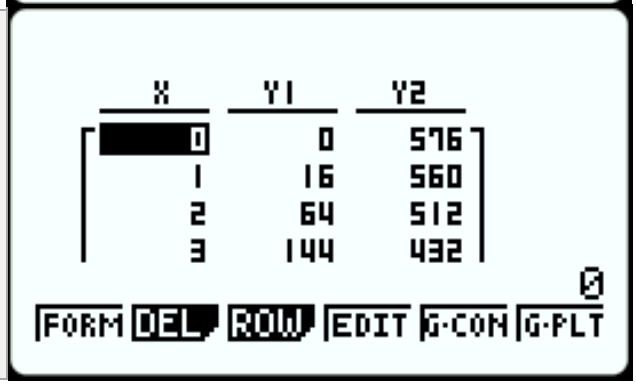

2. Enter Elena's and Diego's expressions describing the object's motion in **Y1** and **Y2** as shown to the right. Press EXE to save each expression.




3. Press F5 – SET to adjust the table settings as shown to the right. We want to see the values in the table for time 0 to 6 seconds, by steps of 1 second. Press EXE when finished.




4. Now you will be back to the screen in Step 2. Press F6 – TABL to view the table to the right.



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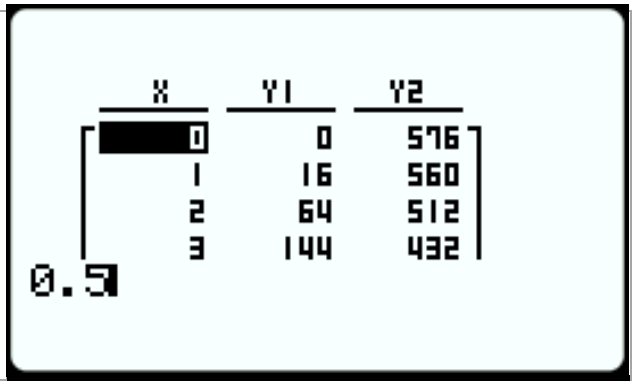
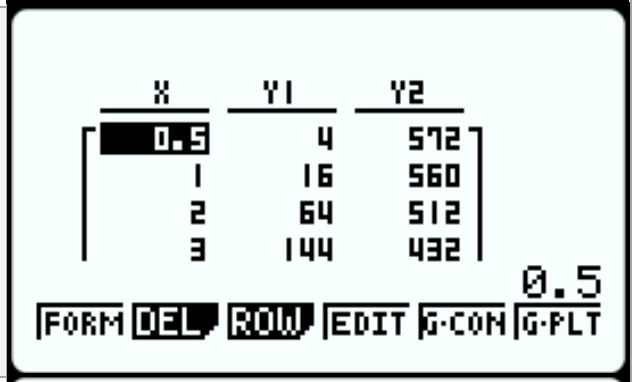
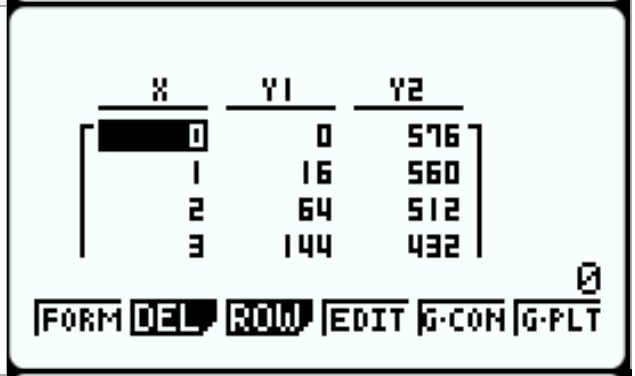
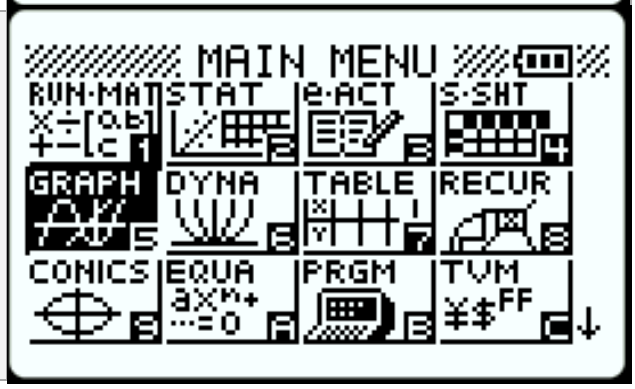
| 5. Students are asked to f**ind** the distance the object falls in 0.5 seconds. This ca**n be** found from Elena's table if we edit a time to be 0.5. While highlighting an **x-value**, type 0.5. |  |
| 6. Press EXE when finished to change the **x-value** to 0.5. From the new value in the table for Y1, we can see the object fell 4 feet in 0.5 seconds. Now |  |
| 7. Change the altered x-value back to the original by retyping the original value and pressing EXE again. |  |
| 8. In the **Activity Synthesis**, students are asked to compare and contrast the table, equation, and graphical representations of Elena's and Diego's models. To view the graphs, press MENU, 5 - GRAPH. |  |

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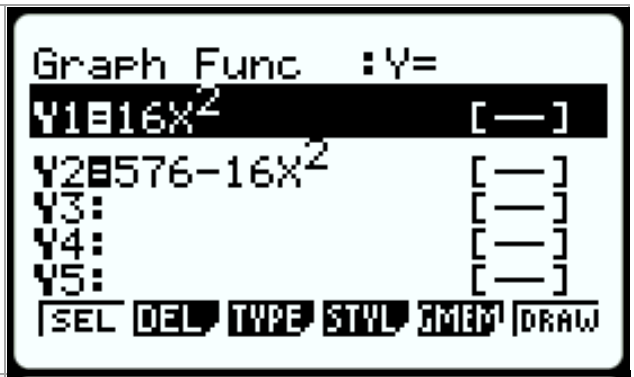
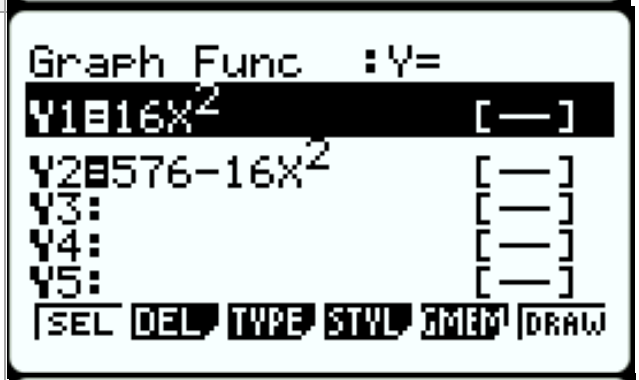
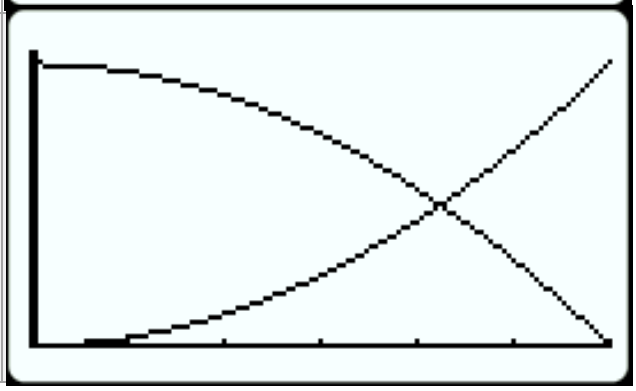
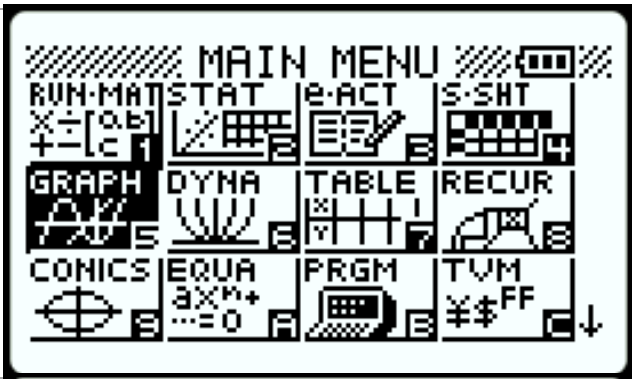
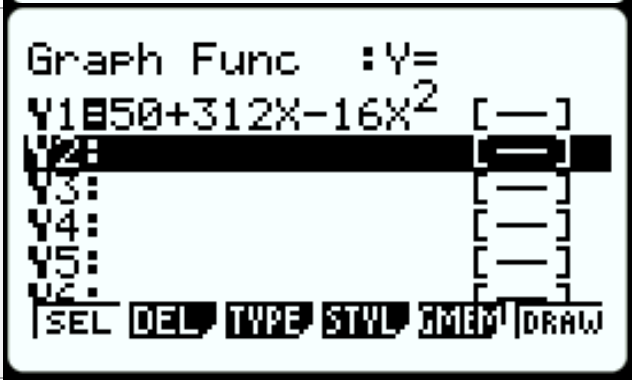
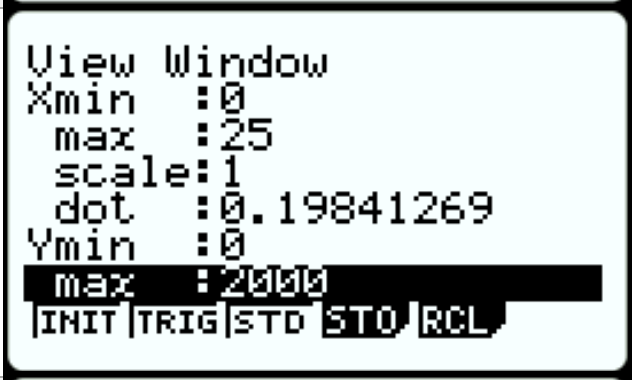
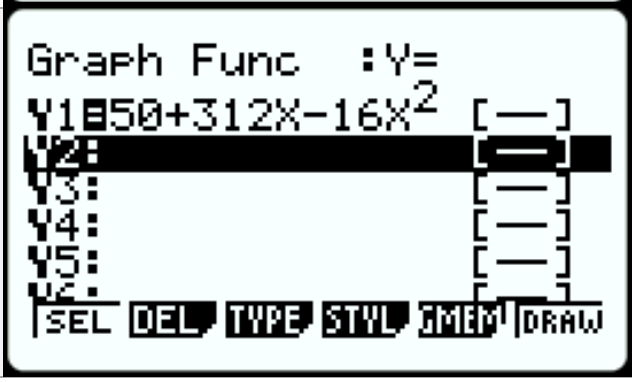
| 9. Our functions are already there from when we entered them in the **Table App**. However, we should adjust the viewing window before we draw them. |  |
| 10. Press SHIFT F3 for TWIN to adjust the window to the values shown to the right. |  |
| 11. When finished, press EXE again to return to the graph function entry window. |  |
| 12. To view the graph, press F6-DRAW. |  |

## Lesson 6 – Modeling the Height of an Object in Projectile Motion

**(Example: IM Lesson 6.3: Graphing Another Cannonball)**

| | |
|---|---|
| 1. In this activity, students are asked to analyze the graph of a projectile to begin relating graph features to context of the problem. To go to the **Graph App**, press MENU, 5 - GRAPH. |  |
| 2. Enter the equation describing the height of the cannon ball into **Y1** as shown to the right. Press EXE when you finish. If you need to delete prior graphs, use F2 – DEL. |  |
| 3. Before we draw the graph, adjust the viewing window by pressing SHIFT F3 for V-Win to adjust the window to the values given in the problem shown to the right. Also, set **Y-Scale** to 100 not shown. |  |
| 4. When finished, press EXE again to return to the graph function entry window. |  |

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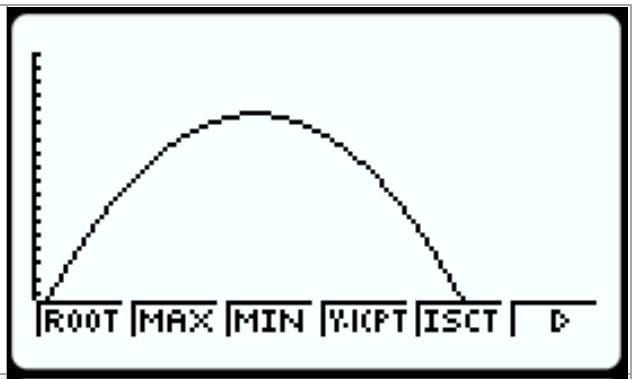
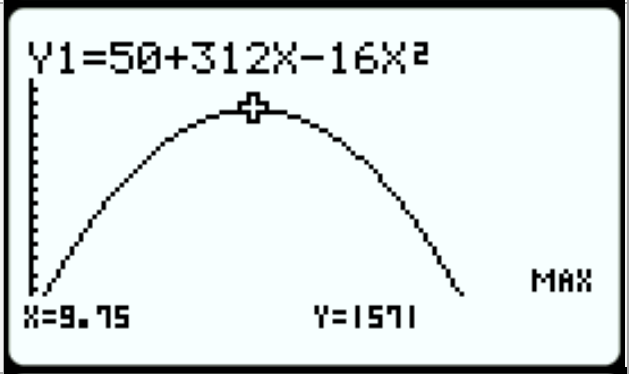
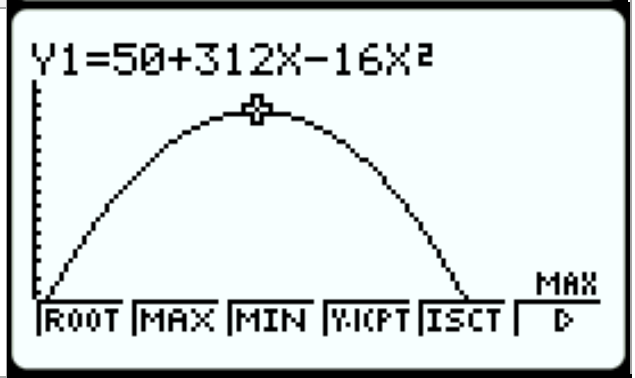
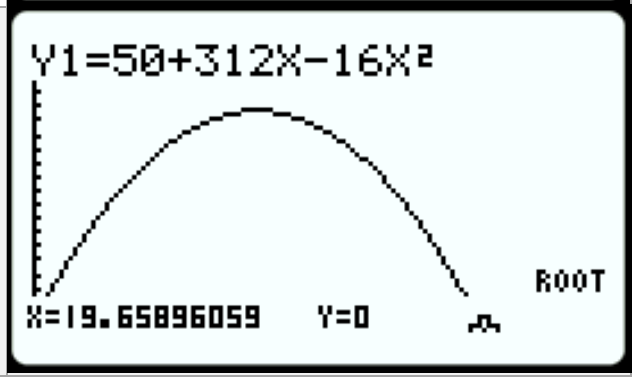
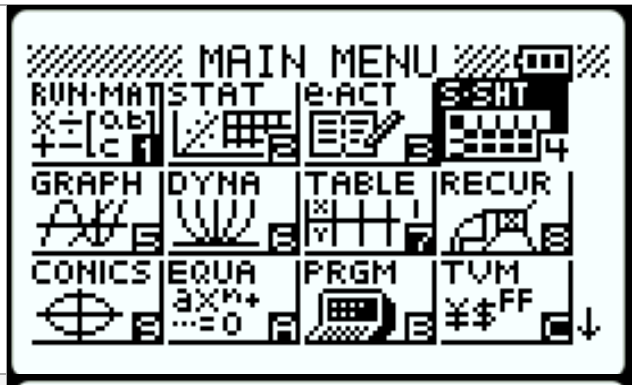
| 5. To view the graph, press F6 – DRAW. From the graph, students are asked to estimate the maximum height. To find the maximum height press F5 – **G-Solv** to see the **Graph-Solve** options. |  |
| 6. Press F2 – MAX. The maximum will be highlighted, and the coordinates will be shown at the bottom of the screen. For this problem the maximum height is 1,571 feet at 9.75 seconds. |  |
| 7. Next, we need to estimate when the cannonball hits the ground. This will occur at the positive root (zero) of the graph. To find the root, press F5 – **G-Solv** again to see the **Graph-Solve** options. |  |
| 8. Press F1 – ROOT. This will display the zero at the bottom of the screen. The cannonball hits the ground after about **19.66 seconds**. Times outside of this domain (0 to 19.66 secs) do not mean anything in the context of the problem. |  |

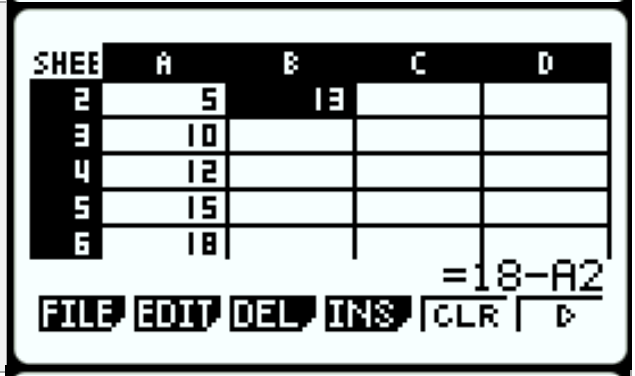
## Lesson 7 – Create a Table to Model & Graph a Quadratic Function

**(Example: IM Lesson 7.2: What Price to Charge?)**

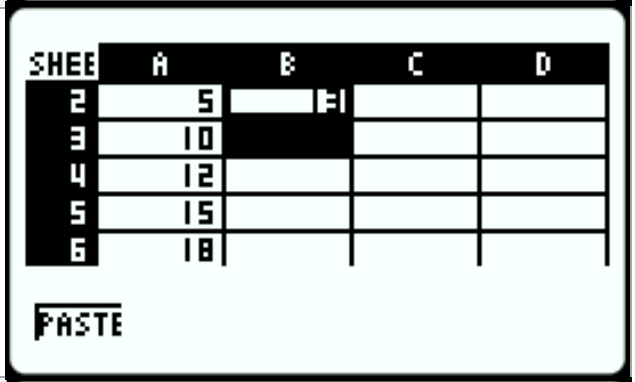
1. We will be creating a table to investigate/model a quadratic equation in a business context. To go to the **Spreadsheet App**, press MENU, 4 - S-SHT.



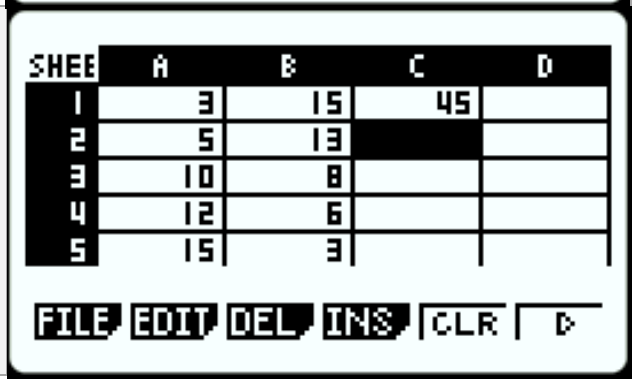

2. In the spreadsheet, begin to complete the table started in the lesson. All three columns can be entered manually, or once the pattern is found the **"Copy-Paste"** or **"Fill"** commands can be used as described in previous lessons.




3. For **Column B**, I used the **"Copy-Paste"** method to complete the column. I copied the formula in **Cell B2** by highlighting it, pressing F2 – EDIT, then F2 – COPY. (Notice the black ring around the cell.) Press the down arrow (▼) to **Cell B3** and paste it by pressing F1 – PASTE. Repeat for the remaining cells in this column.




4. Move to **Cell C2.** To use the "Fill" command for this column, press F2 – EDIT followed by F6 – ▷ to see the next set of commands.



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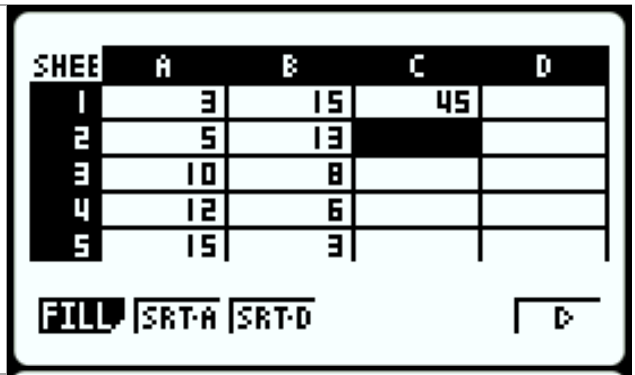
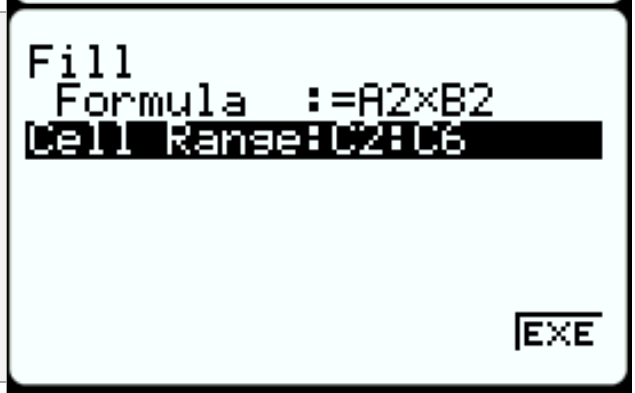
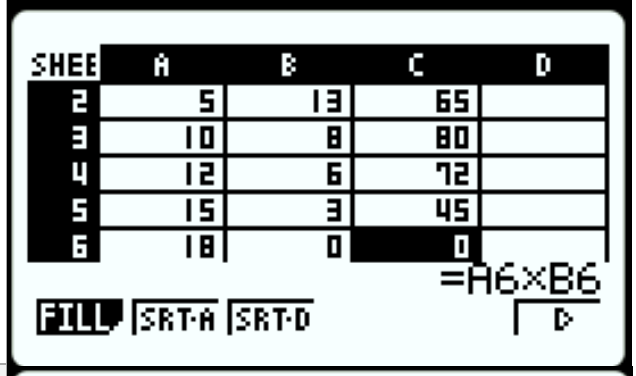
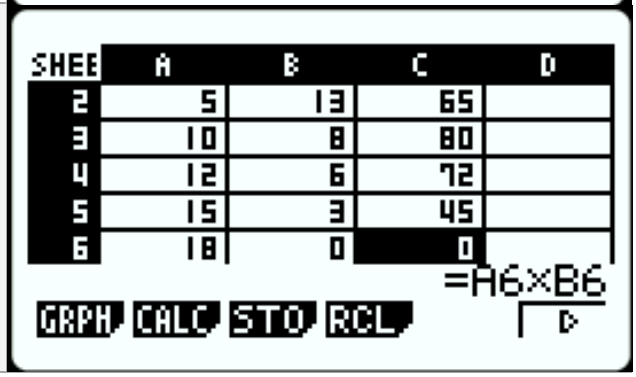
| 5. Now, press F1 – FILL for "**Fill**". To get the revenue for each row, multiply cells **A** and **B** together in cell **C**. |  |
| 6. Enter the formula and edit the cell range as shown. Remember to start the formula with an **=** sign. When complete, press EXE. |  |
| 7. **Column C** should now be complete as shown. |  |
| 8. Next, let's view a scatter plot of price versus revenue. Press EXIT and then F6 – ▷ to view the menu choices shown. |  |

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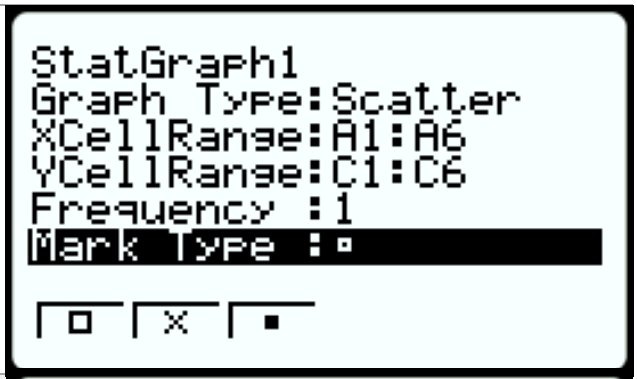
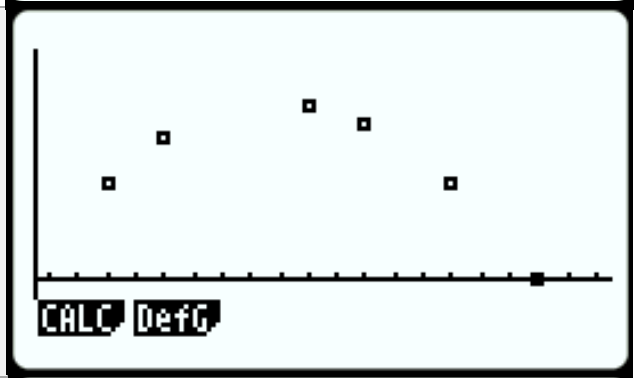
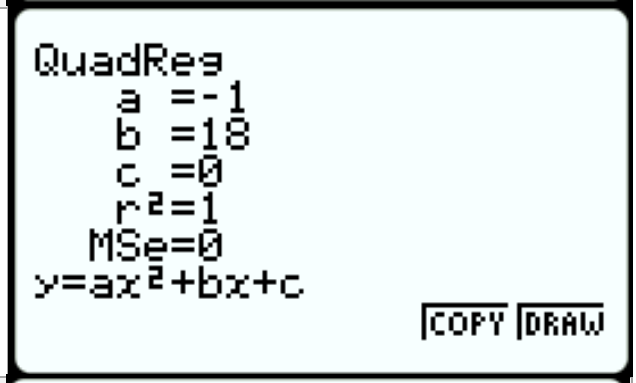
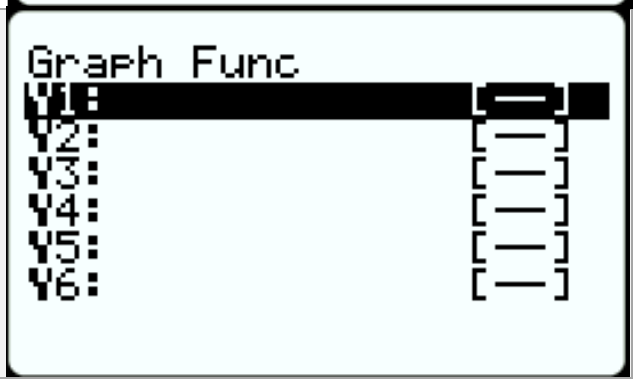
| 9. From here, press F1 – GRPH then F6 – SET to view the setup for **StatGraph1**. Adjust to the settings shown to the right. Press EXE. |  |
| 10. Press F1 – GPH1 to view the scatter plot. |  |
| 11. Press F1 – CALC to enter the **regression** menu. Press F4 – x^2 to view the results of the **Quadratic Regression**. |  |
| 12. To copy this result to the **Graph Function & Table apps**, press F5 – COPY to see this screen. |  |

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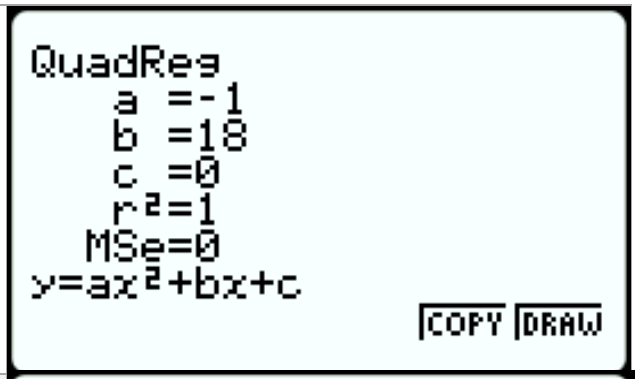
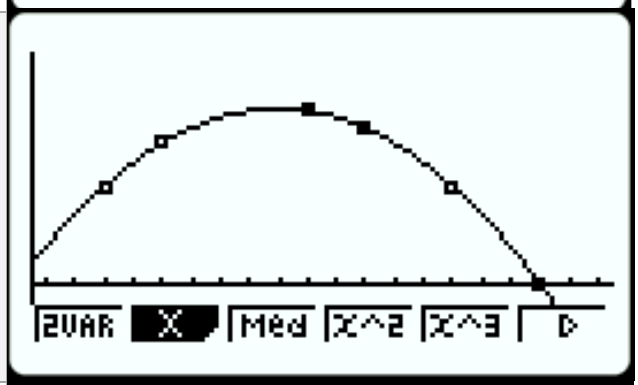
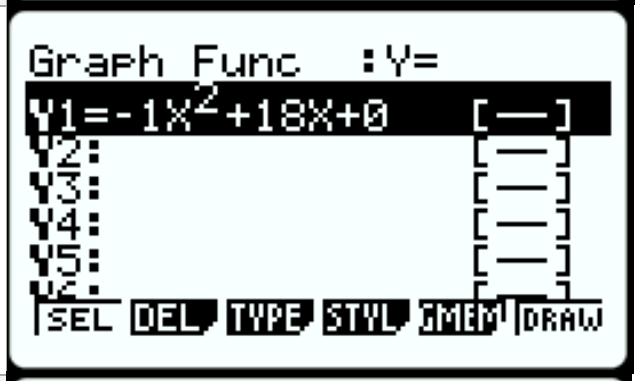
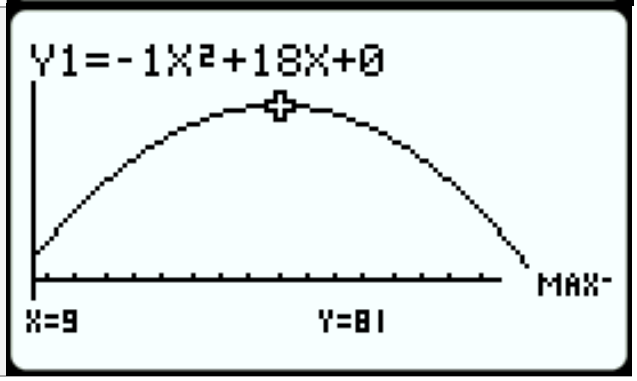
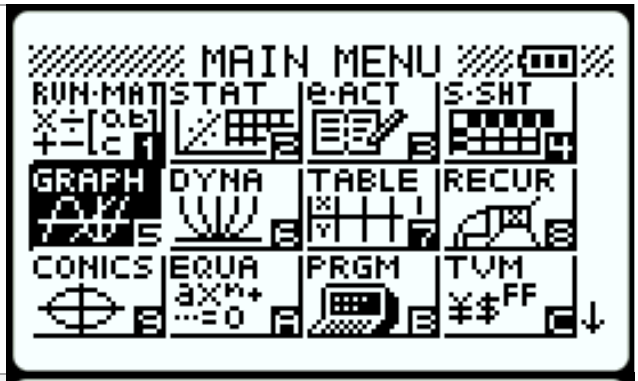
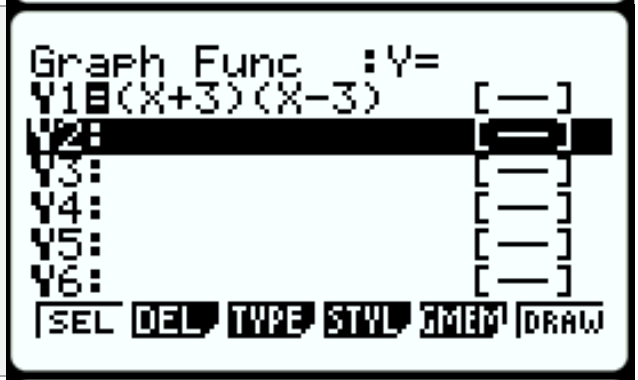
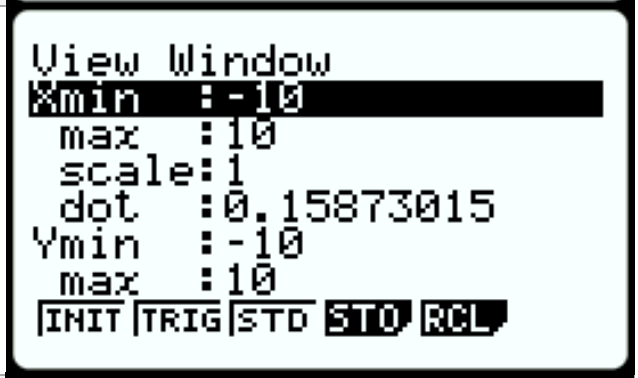
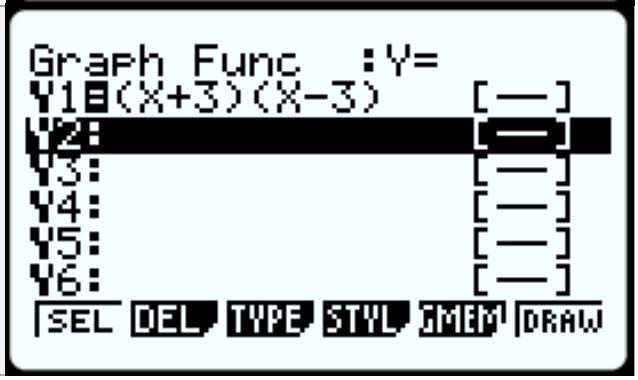
| 13. Press EXE and you will return to the prior page. |  |
| 14. Now press F6-DRAW to view the regression equation on the data plot. |  |
| 15. To analyze this function further, go to the graph app by pressing MENU 5 – GRAPH. As you can see, the regression equation was copied to Y1. |  |
| 16. To find the optimal selling price, draw the graph by pressing F6-DRAW, and then find the maximum by pressing F5-G-SLV, and followed by F2– MAX. The maximum revenue occurs when selling the movie for $9. |  |

## Lesson 11 – Graphing Quadratics to Verify the Vertex and Intercepts

**(Example: IM Lesson 11.3: What Do We Need to Sketch a Graph?)**

| | |
|---|---|
| 1. In this activity, students are asked to apply what they know about x-intercepts and the vertex of quadratic functions to sketch a quadratic with at least 3 identifiable points. Students will verify their predictions by graphing on the calculator. To go to the **Graph App**, press [MENU], [5] - [GRAPH]. |  |
| 2. Students are given three functions in factored form and asked to predict the x-intercepts and the x-coordinate of the vertex. Let's verify the first function, ***f*(*x*) = (*x* + 3)(*x* – 3).** Enter this function for **Y1** and press [EXE] when finished. |  |
| 3. Before graphing, set the view window to a standard window. Press [SHIFT],then [F3]–[V-WIN] followed by [F3]–[STD]. |  |
| 4. Press either [EXE] or [EXIT] to return to the graph entry screen. |  |

| | |
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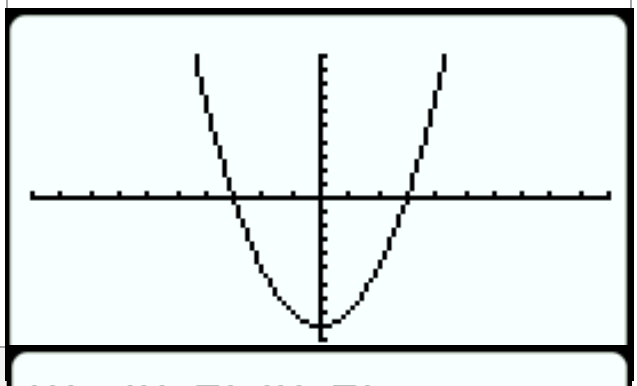
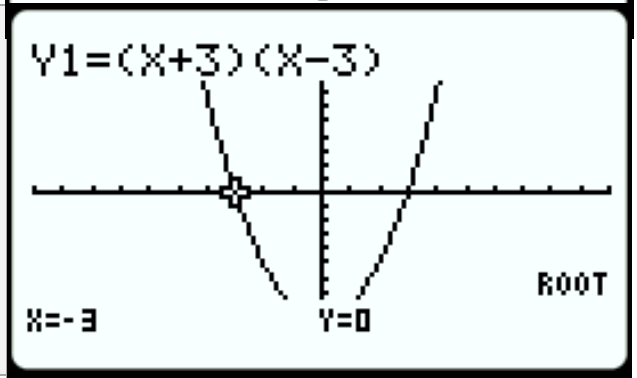
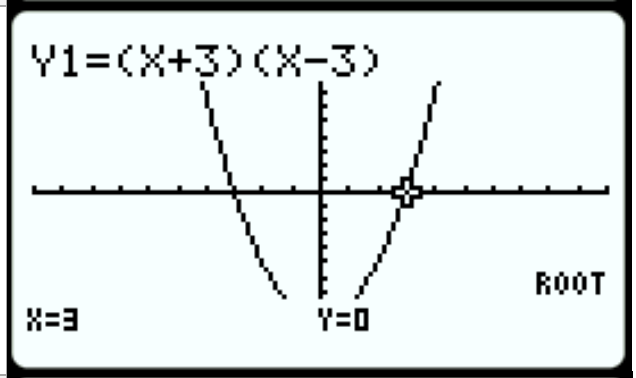
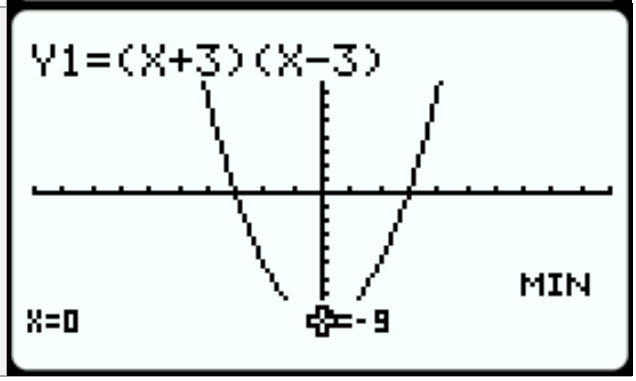
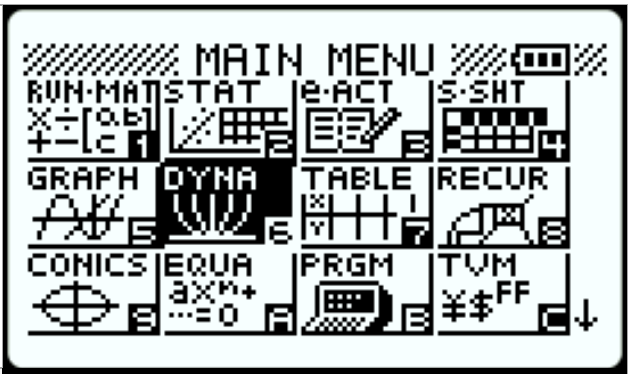
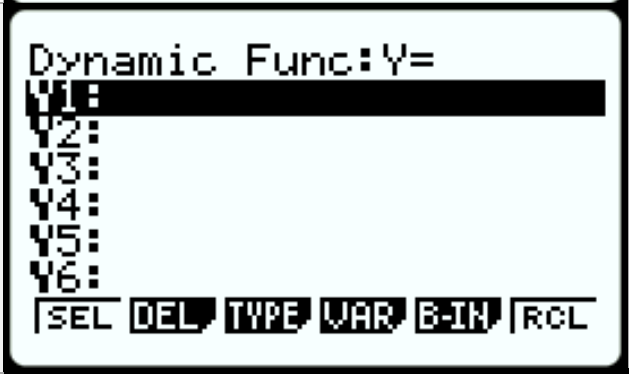
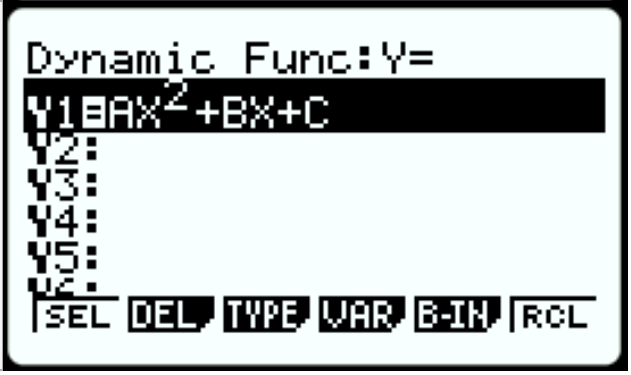
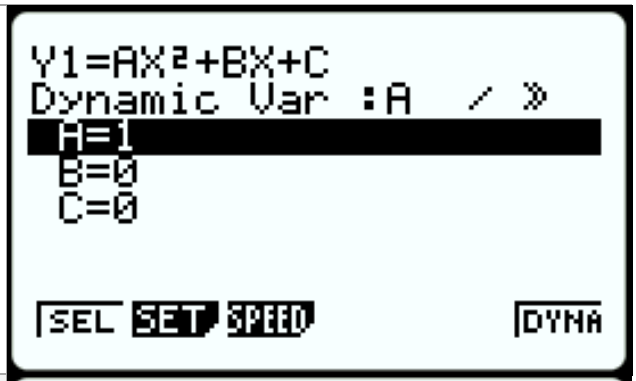
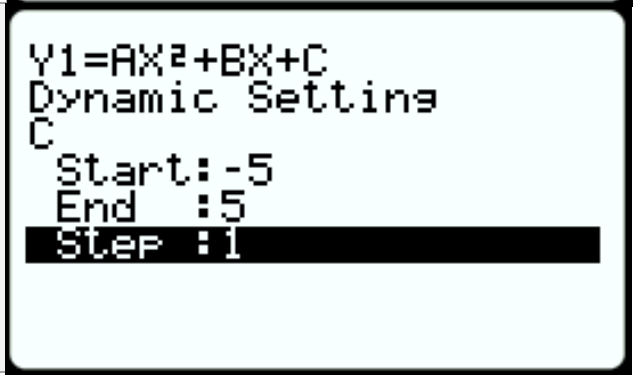
| 5. Now press F6 – DRAW to graph the function. |  |
| 6. To verify the ***x*-intercepts**, or **roots** of the graph, press **F5 – G-Solv** then F1 – ROOT. The coordinates of the first ***x*-intercept** will be displayed at the bottom of the screen. |  |
| 7. To find the second ***x*-intercept**, press the right arrow key, ▶. Its coordinates will automatically appear at the bottom of the screen. |  |
| 8. The ***x*-coordinate** of the **vertex** can be found by finding the **minimum** value, as this parabola **opens up**. (a > 0) To find the minimum of the graph, press **F5 – G-Solv** then F3 – MIN. (If the parabola opened down, press F2 – MAX to find the coordinates of the maximum instead.)<br><br>9. Repeat **Steps 2** through **8** to verify the values for the other two functions. |  |

## Lesson 12 – Using Dynamic Graphing to Explore Quadratics (“a” & “c”)

**(Example: IM Lesson 12.2: Quadratic Graphs Galore.)**

| | |
|---|---|
| 1. This activity allows students to see how the coefficient of the squared term (***a***) and the constant term (***c***) affect the graph of a quadratic function in standard form. Press [MENU] then [6] – [DYNA] to open the **Dynamic Graph App**. |  |
| 2. Functions from the **Graph** or **Table App** are shown here as well. Use [F2] – [DEL] to **delete** them as necessary or [F1] – [SEL] to **deselect** if you want to save a function for later use. |  |
| 3. Press [F5] – [B-IN] for **Built-In functions** to use. Arrow down ▼ twice to highlight the **quadratic function** in **standard form**. |  |
| 4. Press either [EXE] or [F1] – [SEL] to select this template. |  |

| | |
|---|---|
| 5. Now press [F4] – VAR to view/set the initial values for the parameters **A**, **B**, and **C**. |  |
| 6. First, we will examine how changing **C**, the **constant term**, affects the graph. Highlight **C = 0**, as shown to the right. |  |
| 7. Press [F1] – SEL and notice that the **Dynamic Var** has changed from **A** to **C**. |  |
| 8. Press [F2] – SET to change the **start, end,** and **step** values for the current dynamic variable; **C**. Press [EXE] to return to the prior screen in **Step 7**. |  |

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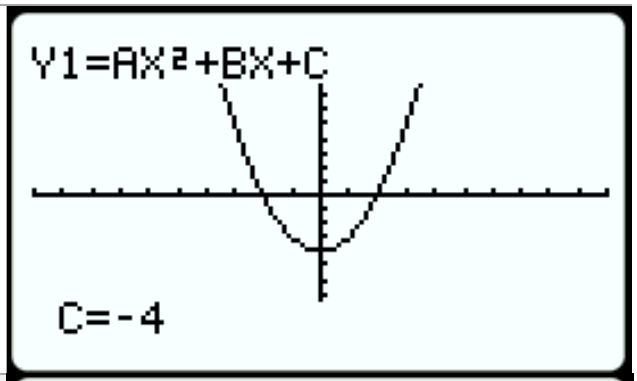
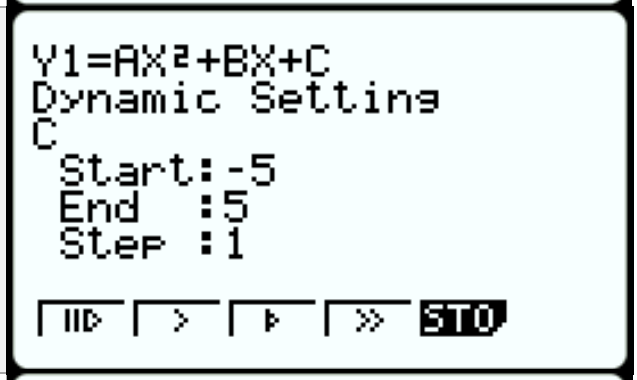
| 9. Press F6 – DYNA to begin. The value of **C** is displayed, as it will cycle from **-5** to **5**, and then back to **-5**, etc. As **C** increases by 1, the graph **moves up one unit**. |  |
| 10. Once completed with the animation, press AC/ON to go to this screen. Here, you can adjust the **speed**, **pause**, **restart** the animation, or **store** the current function. |  |
| 11. Press EXIT to return to the original screen. Note, the last value of **C** in the dynamic graph animation will now show for **C**. Now, we will look at how **A** affects the graph. First, return **C** back to 0; if necessary. |  |
| 12. Now, change the **Dynamic Var** from **C** to **A** by highlighting **A**, and pressing F1 – SEL. |  |

| | |
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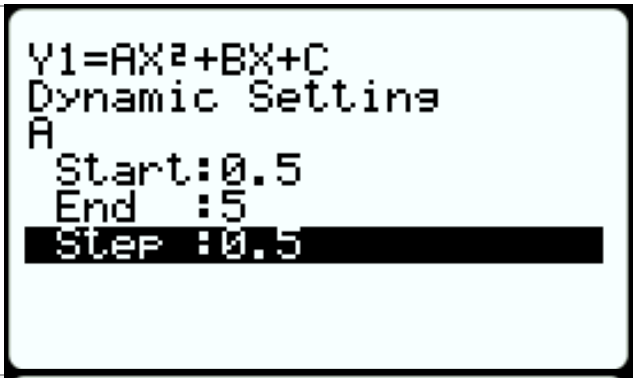
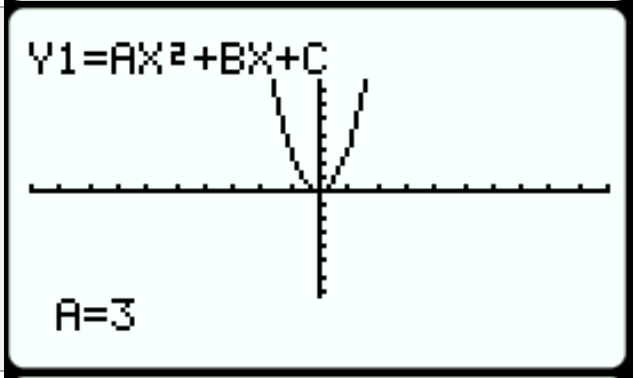
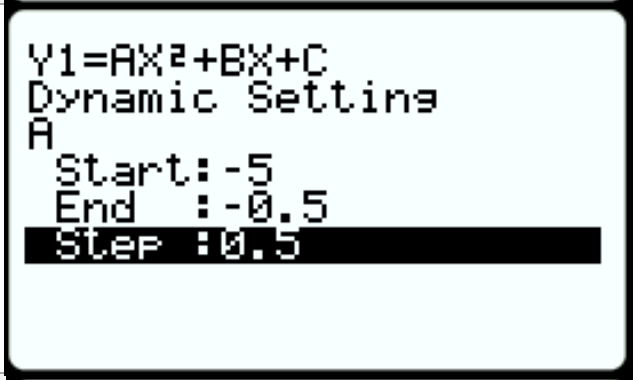
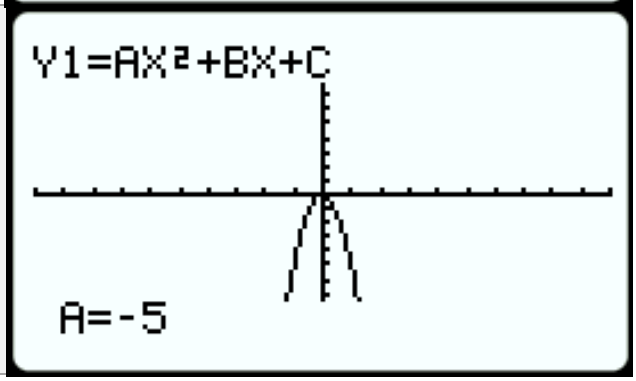
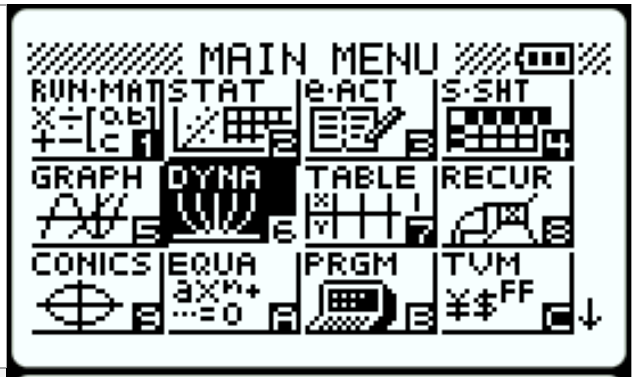
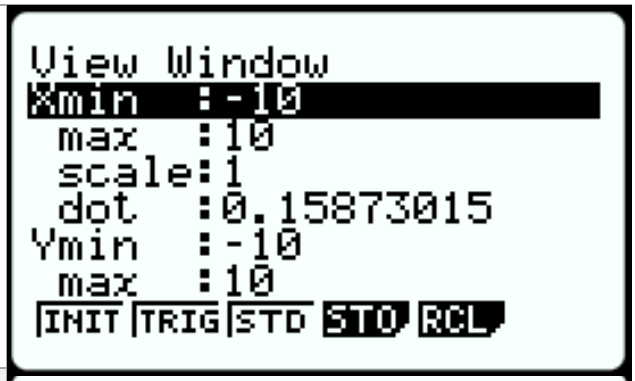
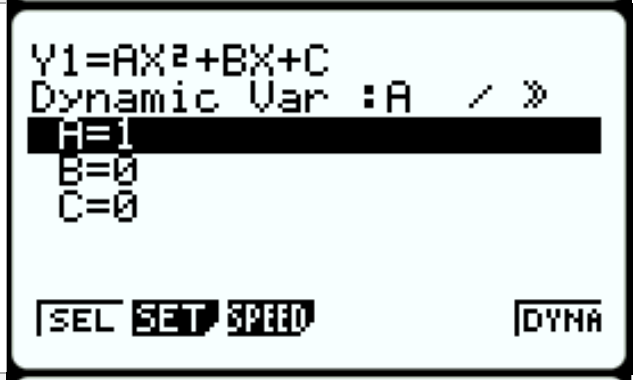
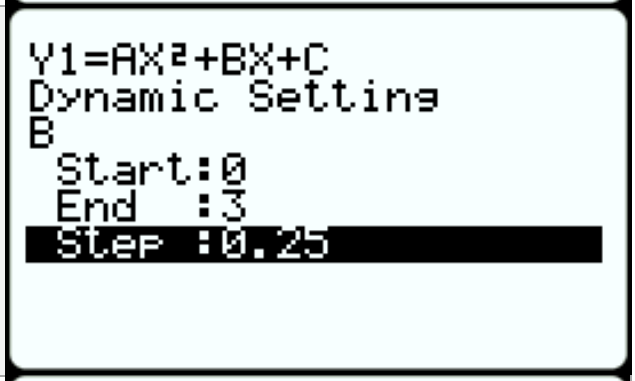
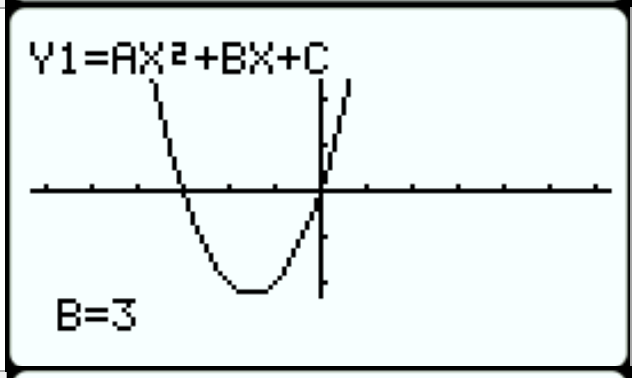
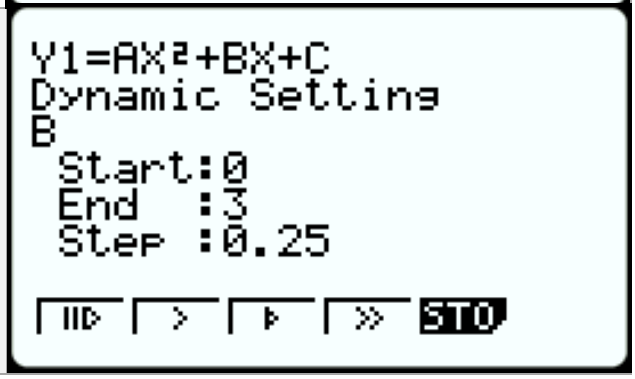
| 13. Focusing on positive values of **A** first, press [F2] – [SET] to change the **start, end**, and **step** values for this variable. Press [EXE] to return to the prior screen in **Step 12**. |  |
| 14. Press [F6] – [DYNA] to begin. The value of **A** is displayed, as it will cycle from **0.5** to **5**, and then back to **0.5**, etc**.** until [AC/ON] is pressed to stop. As the value of **A** increases, the graph is **vertically stretched, appearing narrower**. |  |
| 15. Now, press [EXE] to return to the original screen and then [F2] – [SET] to change the start and end values for this variable, **A**, to **-5** and **-0.5**; respectively. |  |
| 16. Press [EXE] to return to the prior screen in **Step 12**. Press [F6] – [DYNA] to begin. The value of **A** is displayed, as it will cycle from **-5** to **-0.5**, and then back to **-5**, etc**,** until [AC/ON] is pressed to stop. |  |

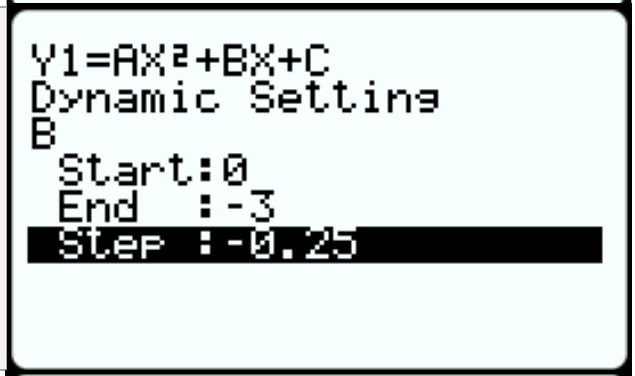
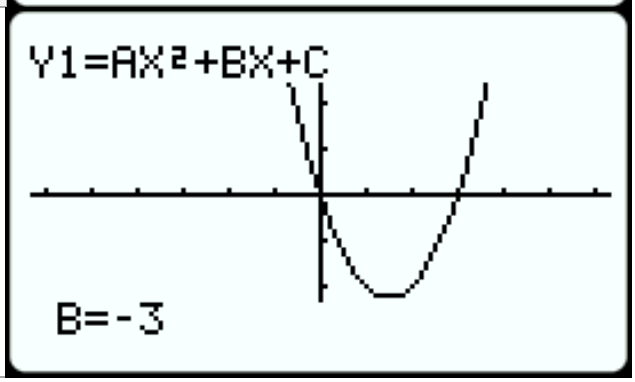
## Lesson 13 – Using Dynamic Graphing to Explore Quadratics ("b"-value)

**(Example: IM Lesson 13.2: What about the Linear Term? – Optional Activity)**

| | |
|---|---|
| 1. This activity allows students to see how the **coefficient** of the **linear term** (***b***) affects the graph of a quadratic function in **standard form**. Press [MENU] then [6] – [DYNA] to open the **Dynamic Graph App**. |  |
| 2. Functions from the **Graph** or **Table App** are shown here as well. Use [F2] – [DEL] to **delete** them as necessary or [F1] – [SEL] to **deselect** if you want to save a function for later use. |  |
| 3. Press [F5] – [B-IN] for **Built-In functions** to use. Arrow down ▼ twice to highlight the **quadratic function** in **standard form**. |  |
| 4. Press either [EXE] or [F1] – [SEL] to select this template. |  |

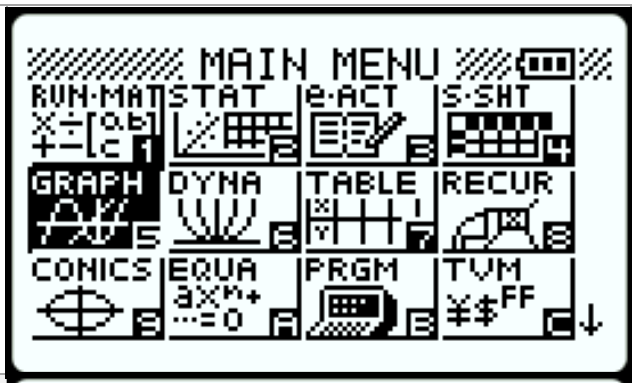
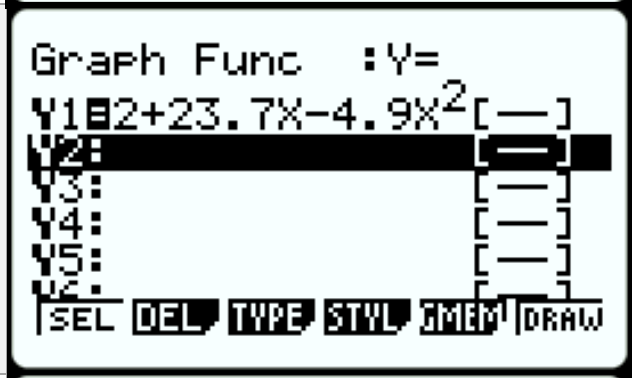
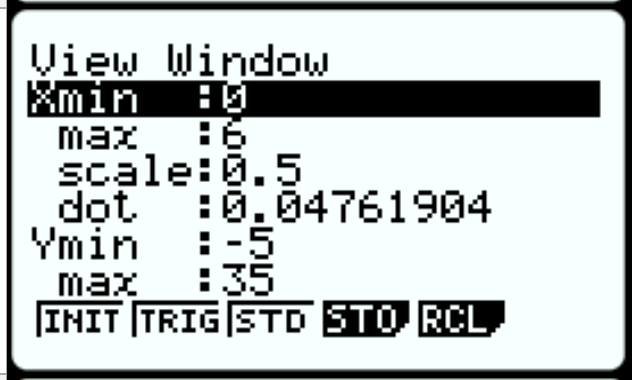
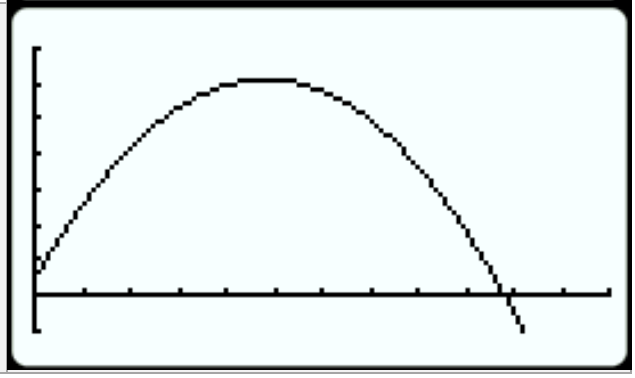
| | |
|---|---|
| 5. The **initial window** will work well for this lesson. Press SHIFT, F3 – V-WIN to go to the **view-window** screen. This calculator is currently showing the **standard window**. |  |
| 6. Switch to the **initial window** values by pressing F1 – INIT. Press EXE to return to the screen in **Step 4**. |  |
| 7. Now press F4 – VAR to view/set the initial values for the parameters **A**, **B**, and **C**. |  |
| 8. Now we will examine how changing **B**, the **coefficient** of the **linear term,** from **0 to 3** affects the graph. Highlight **B = 0**, as shown to the right. |  |

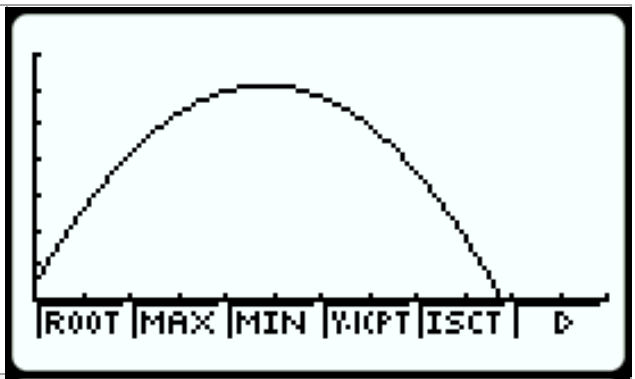
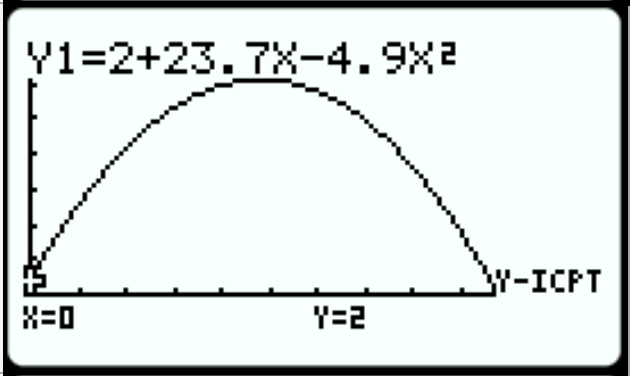
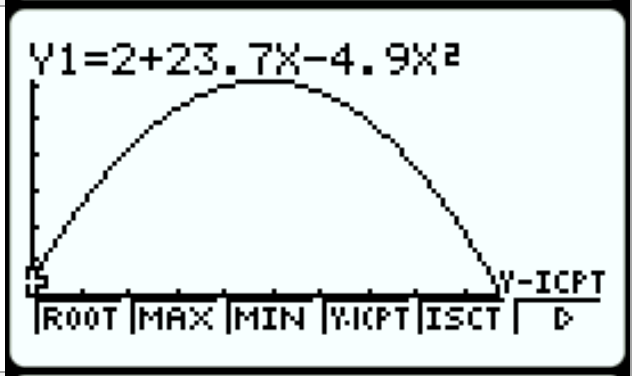
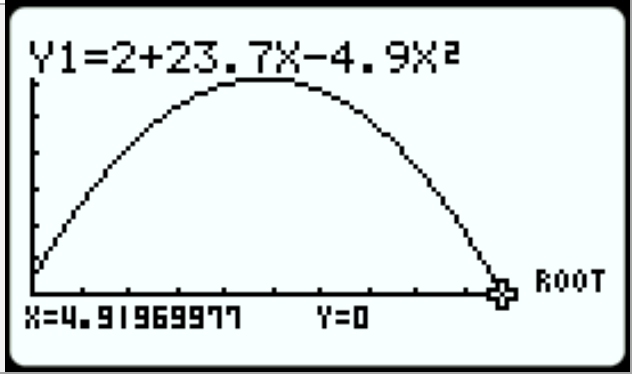
| | |
|---|---|
| 9. Press F1 – SEL and notice that the **Dynamic Var** has changed from **A** to **B**. |  |
| 10. Press F2 – SET to change the start, end, and step values for the current dynamic variable; **B**. Press EXE to return to the prior screen in **Step 9**. |  |
| 11. Press F6 – DYNA to begin. The value of **B** is displayed, as it will cycle from **0** to **3**, and then back to **0**, etc. As **B** increases from **0** to **3**, the graph **moves to the left, and down.** |  |
| 12. Once completed with the animation, press AC/ON to go to this screen. Here, you can adjust the **speed**, **pause**, **restart** the animation, or **store** the current function. |  |

| | |
|---|---|
| 13. Press [EXIT] to return to the original screen. Note, the last value of **B** in the dynamic graph animation will now show for **B**. |  |
| 14. Now, we will focus on how **B** affects the graph when changing from **0** to **-3**, press [F2] – [SET] to change the **start**, **end**, and **step** values for this variable. To move in the **negative** direction, make sure to change the step to a **negative**! Press [EXE] to return to the prior screen in **Step 13**. |  |
| 15. Press [F6] – [DYNA] to begin. The value of **B** is displayed, as it will cycle from **0** to **-3**, and then back to **0**, etc. until [AC/ON] is pressed to stop. As **B** changes from **0** to **-3**, the graph **slides down** and to the **right.** |  |

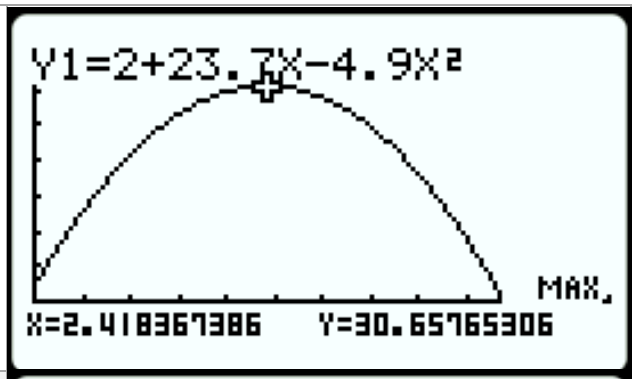
## Lesson 14 – Graphing Quadratic Models to Find Values in Context

**(Example: IM Lesson 14.2: A Catapulted Pumpkin)**

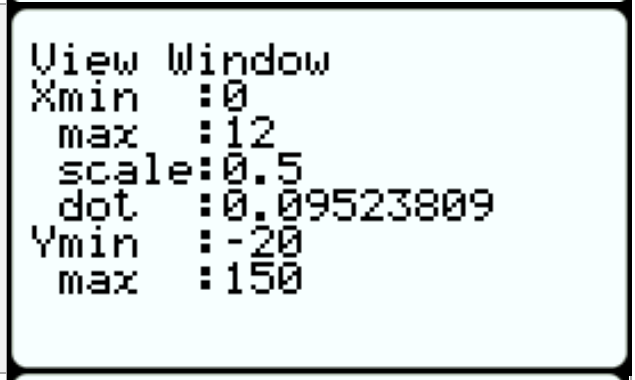
| | |
|---|---|
| 1. Students are asked about information from the quadratic model of a catapulted pumpkin. After, they are asked to verify using technology. Press MENU then 5 – GRAPH to open the **Graph App**. |  |
| 2. Enter the model in for **Y1**, as shown to the right. When finished, press EXE. |  |
| 3. Before drawing the graph, set an appropriate viewing window. Press SHIFT, F3 – WIND to go to the V**iew-Window** screen. Adjust the values as shown to the right. |  |
| 4. Press EXE to return to the screen in **Step 2**. Now press F6 – DRAW to draw the graph. |  |

| | |
|---|---|
| 5. Students are to analyze this model to determine values in context of the problem. To analyze the graph, press **F5 – G-Solv** to view the **graph solve** menu hot keys. |  |
| 6. The **vertical intercept** is the ***y*-intercept** of the graph. Press **F4** – **Y-ICPT** to find this value for this graph. In context, the pumpkin had an **initial height of 2 meters** before being launched. |  |
| 7. Press **F5 – G-Solv** to back out and view the **graph solve** menu hot keys again. |  |
| 8. The **horizontal intercept** is the ***x*-intercept** of the graph. These are the same as the **zeros** or **roots** of a function. To find this value, press **F1** – **ROOT**. In context, the pumpkin was in the air for about **4.9 seconds** before hitting the ground (height of 0 meters). |  |

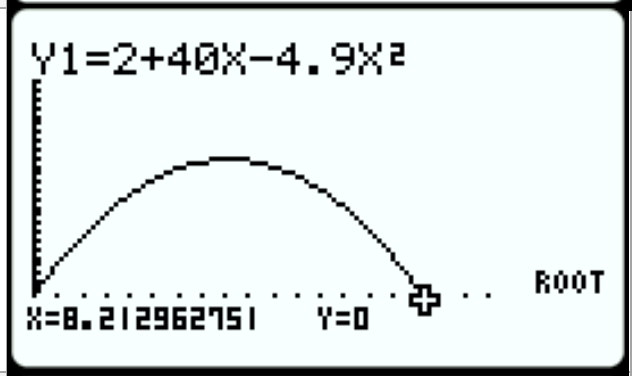
9. Since the quadratic model opens down, the **maximum value** will be the **vertex**. Press F5 **– G-Solv** to back out and view the **graph solve** menu hot keys once again. This time, press F2 – MAX to find the coordinates of the vertex. These coordinates tell us that the pumpkin reached a **maximum height** of about **30.7 meters** around **2.4 seconds** after being fired.




10. The last task of this activity asks to find the **initial velocity** so that the pumpkin is in the air for **10 seconds**. There are multiple ways to determine the new **"*b*" value** in our model. While still in the **Graph App**, students could **increase 23.7**, the **initial velocity** to a value where the **x-intercept** or **root** gets close to **10 seconds**. First, adjust the viewing window by pressing SHIFT, F3 – WIN to go to the **View-Window** screen.



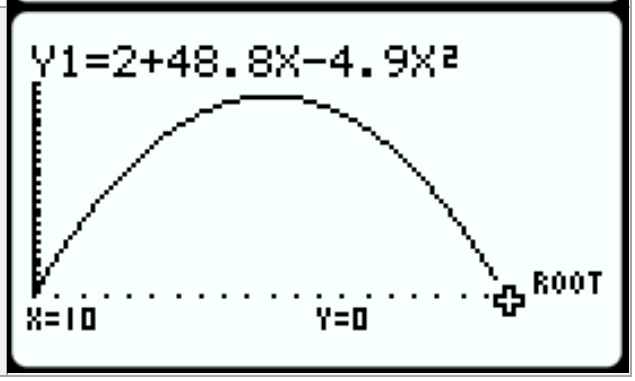

11. Now graphically, use trial and error to change "**b**" on the graph entry window, draw the graph, and see what value gets the root closest to 10 seconds. From this graph, we still need to increase our initial velocity.




12. Since we want the object to hit the ground after 10 seconds, we can find the correct initial velocity numerically by replacing ***x*** with **10** and ***y*** with **0** and then solve for "***b***".

$$0 = 2 + 10b - 4.9(10)^2$$
$$0 = 2 + 10b - 490$$
$$10b = 488$$
$$b = 48.8$$

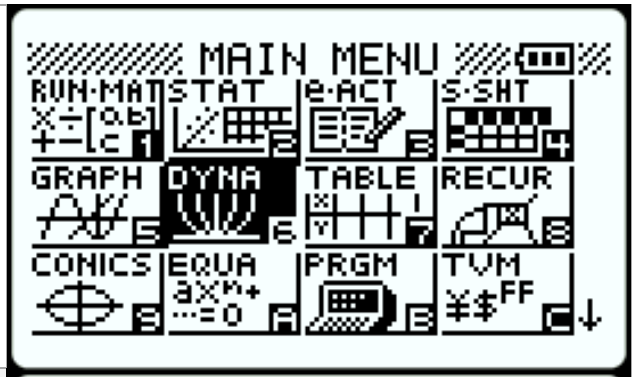
Verifying with the graph, the pumpkin hits the ground **exactly** at **10 seconds**.



## Lesson 15 – Using Dynamic Graphing to Explore Vertex Form

**(Example: IM Lesson 15.3: Playing with Parameters)**

1. This activity allows students to see how the coefficient of the squared term (***a***) and the constant term (***c***) affect the graph of a quadratic function in standard form. Press [MENU] then [6] – [DYNA] to open the **Dynamic Graph App**.

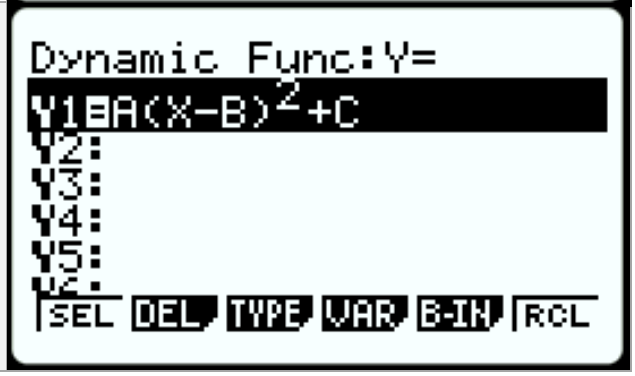


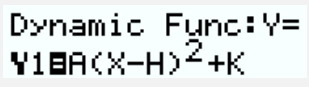

2. Functions from the **Graph** or **Table App** are shown here as well. Use [F2] – [DEL] to **delete** them as necessary or [F1] – [SEL] to **deselect** if you want to save a function for later use.

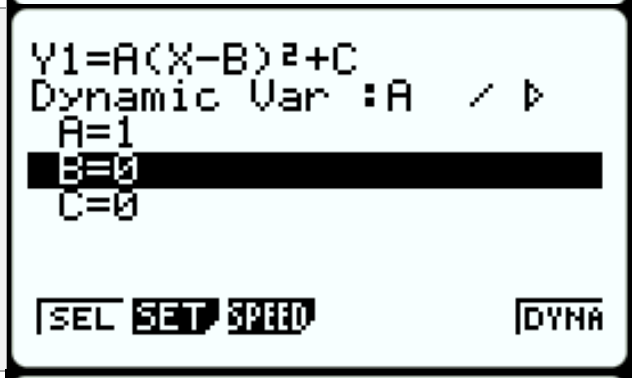
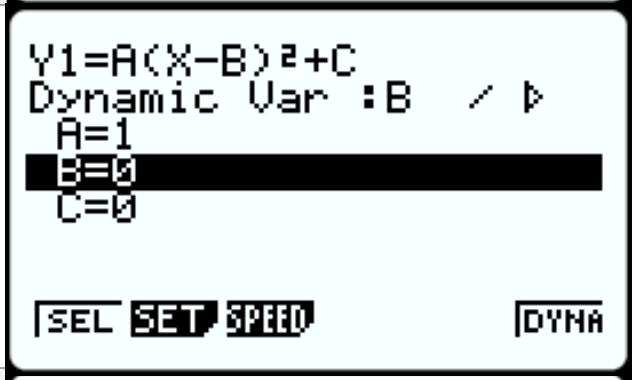
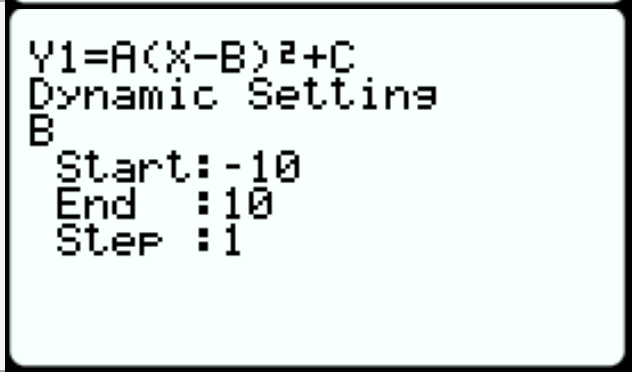

3. You can directly type in any equation with other variables besides "***x***" to create a dynamic animation. Each variable besides "***x***" will create a dynamic variable to animate. However, a **quadratic equation** in **vertex form** is a built-in function. Press [F5] – [B-IN] for **Built-In functions** to use. Arrow down [▼] to highlight the **quadratic function** in **vertex form**, as shown to the right.

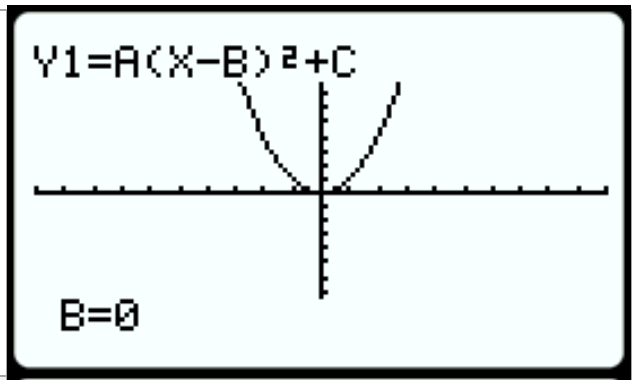
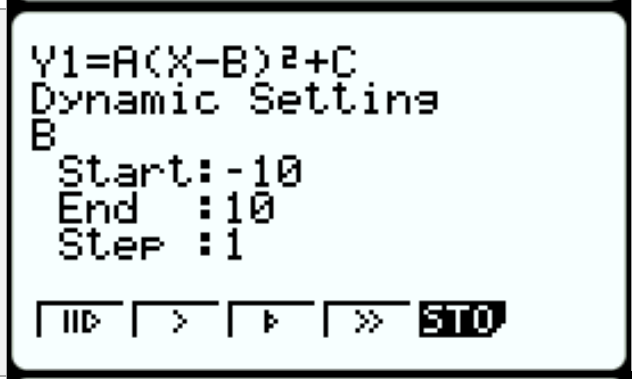
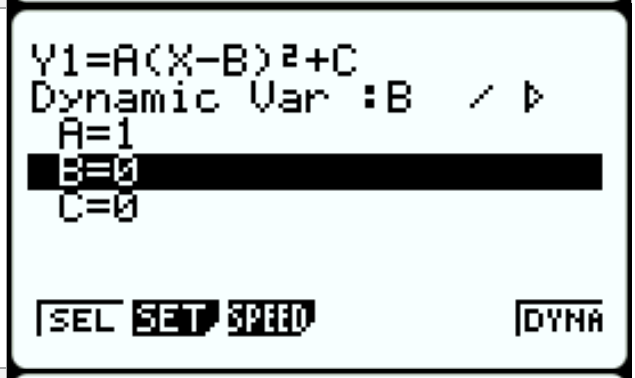

4. Press either [EXE] or [F1] – [SEL] to select this template.

   **Note:** if desired, you can change "**B**" to "**H**" and "**C**" to "**K**" using the arrow and [ALPHA] keys.

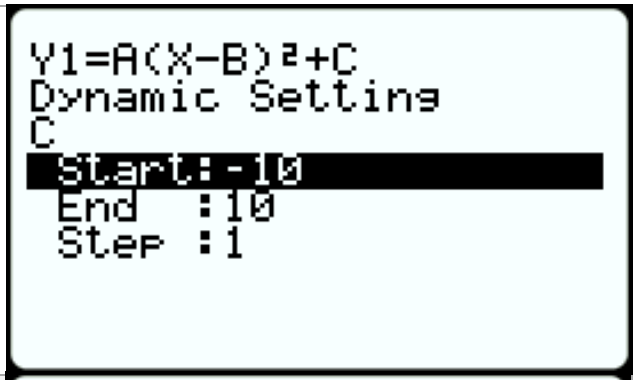


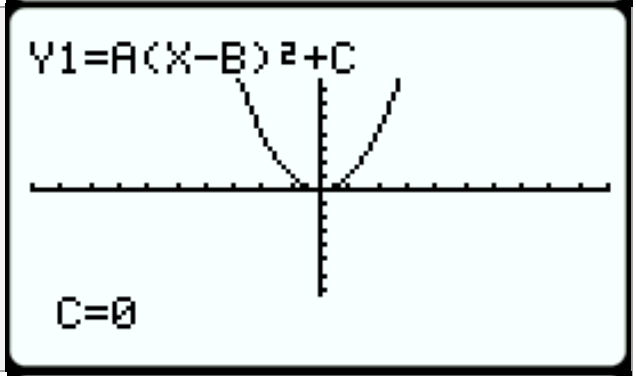
| | |
|---|---|
| 5. Now press F4 – VAR to view/set the initial values for the parameters **A**, **B**, and **C**. First, we will exam the value of "**B**" (or "**H**"). |  |
| 6. Now we will examine how changing **B** affects the graph. Highlight **B = 0**, as shown to the right. |  |
| 7. Press F1 – SEL and notice that the **Dynamic Var** has changed from **A** to **B**. |  |
| 8. Press F2 – SET to change the start, end, and step values for the current dynamic variable; **B**. Press EXE to return to the prior screen in **Step 7**. |  |

| | |
|---|---|
| 9. Press F6 – DYNA to begin. The value of **B** is displayed, as it will cycle from **-10** to **10**, and then back to **-10**, etc. As **B** increases by 1, the graph **moves one unit left**. |  |
| 10. Once completed with the animation, press AC/ON to go to this screen. Here, you can adjust the speed, pause, restart the animation, or store the current function. |  |
| 11. Press EXIT to return to the original screen. Note, the last value of **B** in the dynamic graph animation will now show for **B**. Now, we will look at how **C** affects the graph. First, return **B** back to 0; if necessary. |  |
| 12. Now, change the **Dynamic Var** from **B** to **C** by highlighting **C**, and pressing F1 – SEL. |  |

13. Now, we focusing on how the value of **C** affects the graph, press [F2] – [SET] to change the start, end, and step values for this variable. Press [EXE] to return to the prior screen in **Step 12**.

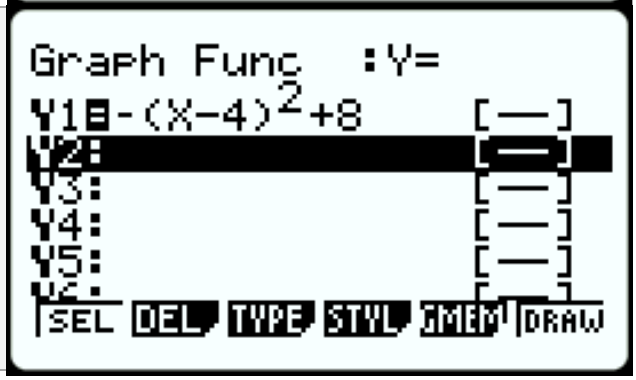



14. Press [F6] – [DYNA] to begin. The value of **C** is displayed, as it will cycle from **-10** to **10**, and then back to -10, etc**.** until [AC/ON] is pressed to stop. As **C** increases by 1, the graph moves **up one unit**.



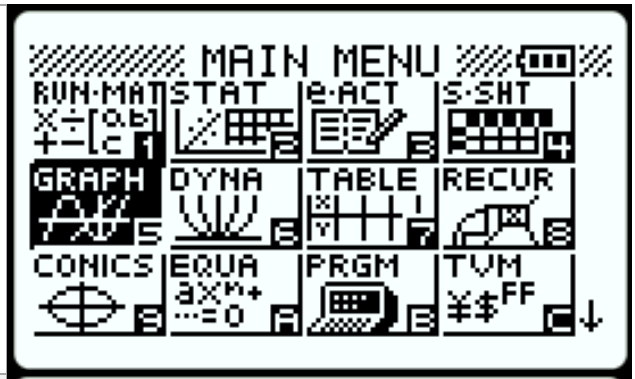
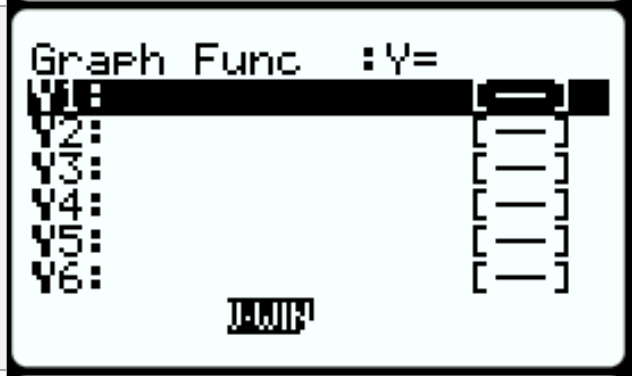
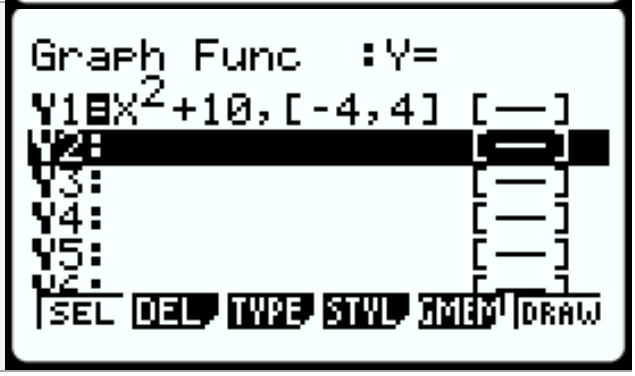

15. Now, press [EXIT] to return to the original screen.

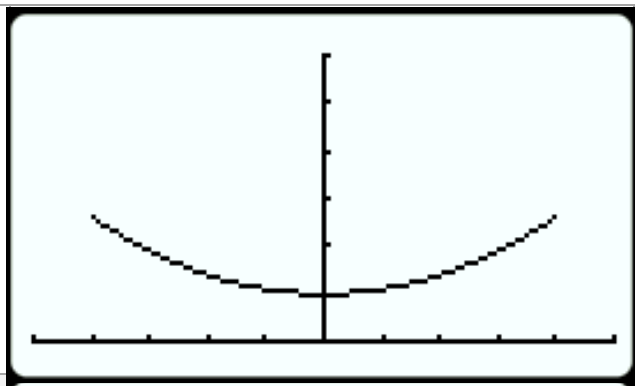
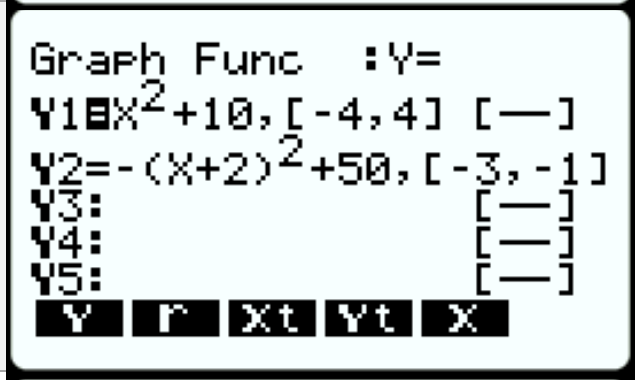
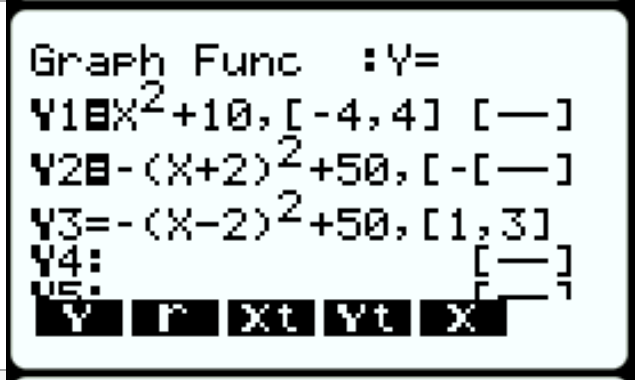
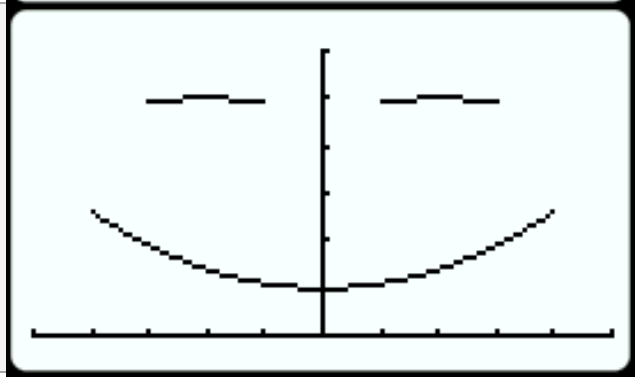

16. From this activity, students should now be able to complete the table to find the **vertex** of the given **quadratic equations** in **vertex form**. Students can verify their answers using the **Graph App** by pressing [MENU] then [5] – [GRAPH]. Enter an equation in **Y1** and pressing [F6] – [DRAW] to view the graph. For this 3rd example in the table, this parabola will **open down (a<1)** with a **vertex** of **(4,8)**.



## Lesson 17 – Graphing Quadratic Functions with Restricted Domains

**(Example: IM Lesson 17.4: Smiley Face.)**

| | |
|---|---|
| 1. In this lesson, we will use **quadratic equations** into graphs of art by **restricting** their **domain**. Press [MENU] then [5] – [GRAPH] to open the **Graph App**. |   |
| 2. First, change the **viewing window** to match the given graph to replicate. Press [SHIFT]. |   |
| 3. Now press [F3] – [V-WIN] to go to the V**iew-Window** screen. Adjust the values as shown to the right to match the given graph. |   |
| 4. Starting with the smile of the graph, it opens upward with a **vertex** located at **(0,10)**. The graph has a **domain** of **-4≤x≤4**. To **restrict the domain** of a graph, after the function enter a **comma**, followed by the interval using **square brackets**, as shown to the right. To obtain the **left** square bracket **( [ )**, press [SHIFT] [+]. The comma, [,], is above the [DEL] key. To obtain the **right** square bracket **( ] )**, press [SHIFT] [−]. Always use the square brackets to restrict domain. |   |

| | |
|---|---|
| 5. Press [F6] – [DRAW] to draw the graph. Our "smile" is now complete. |  |
| 6. Press [EXIT] to return to the graph entry screen. Now enter the **functions** with **restricted domains** to create the eyes. **Y2** to the right shows the function with restricted domain for the left eye. Enter the complete line for **Y2** and then press [EXE]. |  |
| 7. Now, enter the function for the right eye for **Y3**. Enter the complete line for **Y3** and then press [EXE]. |  |
| 8. Press [F6] – [DRAW] to draw the completed graph. Students can be challenged to add other features to their drawing as an extension.<br><br>**Note:** To restrict the domain to **x ≥ a**, enter **[a, ]**. For **x ≤ a**, enter **[ , a]**. An **empty space** on the interval will be interpreted as an **infinity**. |  |